Aortic knob diameter in chest radiographs of healthy adults in Uganda.

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Abstract

Background

The burden of cardiovascular diseases, such as aortic and degenerative diseases grows in the aging population. Chest radiograph still plays an important role in the diagnosis of cardiovascular diseases. Aortic knob diameter in chest radiographs can be used to evaluate early changes of the aortic structure and together with clinical and laboratory findings. This study was aimed at determining the mean values of aortic knob diameter among healthy adults in Uganda.

Methods

We conducted a descriptive cross-sectional study in three selected hospitals in Kampala Uganda. All participants had normal chest radiographs without radiological evidence of cardiovascular disease. Chest radiograph findings extracted included aortic knob diameter, aortic arch diameter, transverse heart diameter and transverse thoracic diameter. All films were independently examined by two experienced radiologists.

Results

We analyzed chest radiograph findings of 294 participants, of which 204 (69.4%) were male. Aortic knob diameter increased with age ($p = 0.000$). The mean aortic knob diameter of males was higher than for females ($3.14 \pm 0.34\text{cm}$ versus $2.77 \pm 0.37\text{cm}$, $p = 0.000$). The mean aortic knob diameter on the digital screen were higher than plain films ($3.03 \pm 0.393\text{cm}$ versus $2.96 \pm 0.392\text{cm}$, $p = 0.000$). Aortic knob diameter positively correlated with age ($p = 0.000$) and aortic arch diameter ($p = 0.000$). Aortic knob diameter also correlated positively with transverse thoracic diameter ($p = 0.05$), transverse heart diameter ($p = 0.05$) and cardiothoracic ratios ($p = 0.05$).

Conclusion

The aortic knob diameter was higher in males and there was a positive correlation with age, aortic arch diameter, transverse heart diameter and transverse thoracic diameter. Aortic knob diameter measurements should be done on digital screen than printed x ray films.

Background

Cardiovascular disease accounts for three quarters of all global estimated deaths in the low- and middle-income countries (1). Chest radiograph remains an important tool for investigation of cardiovascular conditions despite the advent of newer and more sophisticated imaging modalities such as echocardiography, computerized tomography (CT) and magnetic resonance imaging (MRI) in the world

(2). This is mainly due to more readily available and comparatively cheaper costs of performing chest radiograph and still provides valuable clues to diagnosis of cardiovascular pathology (3).

The aorta is a major vascular supply of the human body and also plays an important role in the control of systemic vascular resistance and heart rate. This control is done via pressure-responsive receptors located in the ascending aorta and aortic arch (4). An increase and decrease in aortic pressure results in a decrease of heart rate and systemic vascular resistance, and an increase of heart rate and systemic vascular resistance respectively (5).

The Aortic knob is an important structure that refers to the hump-shaped contour of the aorta seen in a frontal chest radiograph on the left mediastinal silhouette (6). Abnormal aortic knuckle shape, enlargement and aortic nipple, may give the first clue of cardiovascular disease (7). The aortic knob can be enlarged due to increased pressure flow in aorta, increased volume or changes in the elasticity of its wall. In adults, aortic knob enlargement can be seen in systemic hypertension, valvular insufficiency, aortic dissection, traumatic aortic injury, thoracic aortic aneurysm, and atherosclerosis (8).

Aortic knob diameter (AKD) has been shown to be a good predictor of target organ damage with a sensitivity ranging between 70–90% for different cardiovascular conditions, even in early disease (9). These include hypertensive heart disease, sub clinical atherosclerosis, aneurysms and aortic dissection (10). Moreover, aortic knob width is positively correlated with both systolic and diastolic blood pressures (10–12).

Uganda is a low income country and yet is experiencing a shift in major causes of death with coronary artery disease and other forms of heart failure on the rise (13). And the normal AKD in the literature were taken from studies done among Caucasians, Americans, South Koreans, Indians and West Africans. These studies showed that variations exist amongst different populations, age groups and between sexes (14). In this study therefore, we sought to determine the normal AKD amongst healthy adults in Ugandan.

Methods

Study design and setting

This was a descriptive cross-sectional study conducted in three selected tertiary hospitals – CASE hospital, St Francis Hospital and Kiruddu Hospital – Kampala, Uganda from January 2020 to June 2020. St. Francis Hospital is located on Nsambya hill in Makindye Division, one of the five administrative divisions of the city. It lies approximately 5 kilometers southeast of the central business district of Kampala. It is a tertiary referral hospital with a capacity of 361 beds and approximately 450 chest radiographs are performed per month. Kiruddu General Hospital, is in the neighborhood of Kiruddu, on Buziga Hill, in Makindye Division, one of the five administrative units of the Kampala capital city authority. It is approximately 13 kilometers, by road, south-east of the Mulago national referral hospital. Chest radiographs are performed as part of ongoing recruitment in government agencies like police, army

and local governments. Case hospital is an urban, private, tertiary hospital in Kampala, Uganda. It is located at 67 - 71 Buganda Road, on Nakasero hill. Around 100 chest radiographs are performed per a month.

Study population

Study participants included asymptomatic participants referred for chest radiograph examination for the purpose of pre-employment and pre-travel medical check-ups and were recruited in this study. Participants with normal chest radiograph (Posterior anterior view, erect), and age between 18-90 years, with no thoracic skeletal deformity, no known cardio-vascular disease, and normal blood pressure for age (blood pressure chart) were included in the study. Participants whose chest radiographs had significant rotation (>0.5cm) or artifacts were excluded from the study.

Sample size

A sample size of 294 participants was used using the formula proposed by Rosner B. 2015 as summarized below.

$$N = (Z_{\alpha/2} + Z_{\beta})^2 * 2 * \sigma^2 / d^2$$

Where N = sample size required. $Z_{\alpha/2}$ = is the critical value of the Normal distribution at $\alpha/2$ (e.g. for a confidence level of 95%, α is 0.05 and the critical value is 1.96), Z_{β} = is the critical value of the Normal distribution at β (e.g. for a power of 80%, β is 0.2 and the critical value is 0.84), σ^2 = is the population variance, d = desired level of precision/marginal error (1).

$N = (1.96 + 0.84)^2 * 2 * (4.1)^2 / (1)^2$. N=264. Non-response of 10% was 30. Hence the sample size was 294.

Study Procedure

Study participants who gave their consent were physically examined and enrolled into the study. A total of 294 participants' postero-anterior (PA) chest radiographs were obtained. The PA chest radiograph of all the candidates were taken in the erect position with a film focus distance of 1.8m. The exposures were made at normal arrested inspiration. Participant's name, sex, age, height and medical history were recorded. Normal chest radiograph was confirmed by two independent radiologists. Parameters such as AKD, transverse thoracic diameter (TTD) and transverse heart diameter (THD) were evaluated for each patient (figure 1). The aortic knob diameter was measured as the maximum transverse diameter from the lateral border of the air in the trachea to the lateral border of the aortic knob (15). The Aortic arch diameter (AAD) was measured as the most lateral extension to the right and left of the midline at the level of the aortic knob. TTD was measured as the maximum horizontal distance between the internal margins of the chest wall at the level of the right hemi diaphragm (16, 17). THD was measured as the sum of the maximum projection to the right and left heart borders from midline (16, 17).

Data analysis

A structured data collection tool was used to collect bio-demographics and relevant history (Appendix 1). Data was analyzed using STATA version 16. Descriptive statistics for continuous variables were presented as mean and standard deviation. Spear man rank correlation was used to test for the correlation between the aortic diameter measurements with continuous independent variables. In addition, Student t test was performed to test for the mean difference of AKD between groups. A $p < 0.05$ was considered statistically significant.

Results

A total of 294 participants, of whom 204(69.4%) were male and the age range between 18-89 years were recruited in the study. Overall, 196 (66.7%) participants were attending the hospital for pre-employment medical exam, 92 (31.3%) came for annual medical checkup exams, and 6 (2%) pre travel exams. The mean age of the participants was 35.3 ± 10.5 . (Table 1).

Table 1
Age distribution of the participants

Age category	Female (f, %)	Male (f, %)	Total (f, %)
18-29years	40(39.6)	61(60.4)	101(34.4)
30-39years	27(29.4)	65(70.6)	92(31.3)
40-49years	15(20.6)	58(79.4)	73(24.8)
50-59years	7(28.0)	18(72.0)	25(8.5)
≥ 60 years	1(33.3)	2(66.7)	3(1.0)
Total	90(30.6)	204(69.4)	294(100)

Male participants had significantly higher mean AKD compared to their female counterparts (3.14 ± 0.34 cm versus 2.77 ± 0.37 cm, $p = 0.000$). Those in the age group of 50-59years had significantly higher means than younger people in the age group of 18-29 years (Table 2 and Table 3).

Table 2
The mean aortic knob diameter of 294 participants.

Variables	Frequency n=294	Mean $\pm$ SD /cm	P-value
Gender			
Male	204	3.14 $\pm$ 0.34	0.000
Female	90	2.77 $\pm$ 0.37	
Age category			
18-29years	101	2.76 $\pm$ 0.34	0.000
30-39years	92	3.01 $\pm$ 0.30	
40-49years	73	3.26 $\pm$ 0.33	
50-59years	25	3.43 $\pm$ 0.30	
$\geq$ 60 years	3	3.34 $\pm$ 0.56	

Table 3
Comparison of aortic knob diameter in males and females by age.

Males				Females			
Age/yrs.	Mean/cm	SD	P- value	Age/yrs.	Mean/cm	SD	P-value
18-29	2.93	0.28	0.0000	18-29	2.30	0.22	0.0000
30-39	3.07	0.29		30-39	2.86	0.25	
40-49	3.32	0.32		40-49	3.05	0.32	
50-59	3.46	0.27		50-59	3.34	0.37	
≥ 60	3.50	0.69		≥ 60	3.02	0.00	
Men have higher mean aortic knob diameters among all age groups compared to the females.							

The mean AKD was higher when measurement was done on a digital screen than on the chest radiograph film (3.03 $\pm$ 0.393cm versus 2.96 $\pm$ 0.392cm, p - 0.000). However, the males still had significantly higher AKD compared to female and unit increase in age would also increase the AKD (Table 5).

Table 5

The aortic knob diameter measurement on digital screen and x-ray by gender and age groups of 294 participants.

Variables	n=294	aortic knob diameter digital screen	P-value	aortic knob diameter x ray film	P value
		Mean ± SD /mm		Mean ± SD /mm	
Aortic knob diameter	294	3.03±0.393		2.96±0.392	0.000
Gender					
Male	204	3.14±0.34	0.000	3.08±0.37	0.000
Female	90	2.77±0.37		2.70±0.37	
Age category					
18-29years	101	2.76±0.34	0.000	2.71±0.24	0.000
30-39years	92	3.01±0.30		2.92±0.27	
40-49years	73	3.26±0.33		3.20±0.37	
50-59years	25	3.43±0.30		3.39±0.47	
≥60 years	3	3.34±0.56		3.67±0.58	

The average AKD of the sample population was 3.03 $\pm$ 0.39cm, the smallest was 2.2cm and the largest was 4.1 cm. The mean AAD of the study population was 5.63 $\pm$ 0.64cm and average cardiothoracic ratio is 0.446 $\pm$ 0.037 with highest being 0.522cm and lowest 0.366cm (Table 6).

Table 6

Other cardiovascular parameters on chest x-ray for 294 participants

Variables (unit measures)	N	Mean $\pm$ SD	Minimum	Maximum
Aortic knob diameter (cm)	294	3.03 $\pm$ 0.39	2.2	4.1
Aortic arch diameter (cm)	294	5.63 $\pm$ 0.64	4.11	7.63
Transvers heart diameter (cm)	294	12.97 $\pm$ 1.26	10.03	16.43
Transverse thoracic diameter (cm)	294	29.07 $\pm$ 2.78	27.4	36.89
Cardiothoracic ratio	294	0.446 $\pm$ 0.037	0.366	0.522

AKD was strongly and more positively correlated with age among the females than in males, the coefficient was higher among the females and the relationship was statistically significant at 95% confidence level $r=0.7411$ p -value 0.000 for females vs. $r=0.5191$ p -value 0.000 for males. Strong positive correlation was also observed between the AKD and AAD for both male and female. However, AKD was weakly correlated with THD, TTD and cardiothoracic ratio respectively (Table 7).

Table 7: Correlation of the aortic knob diameter with Aortic arch diameter, transverse diameter of the chest and heart diameter for male and female population. (Spearman correlation)

Variables	Correlation coefficient (r) for male	P- value	Correlation coefficient (r) for female	P- value
Age(years)	0.5191	0.05	0.7411	0.05
Aortic arch diameter/cm	0.6136	0.05	0.6518	0.05
Transverse Heart diameter/cm	0.4879	0.05	0.4869	0.05
Transverse thoracic diameter/cm	0.2007	0.05	0.4555	0.05
Cardiothoracic ratio	0.3433	0.05	0.1914	0.05

Weight and height were weakly correlated though positively associated with the aortic knob diameter across both genders. However, it was all higher among the female counterpart and the relationships were not statistically significant at 95% confidence level.

Discussion

This study sought to determine the aortic knob diameter in chest radiographs of healthy adults in Uganda. The results of our study showed that AKD increases with age in both sexes. This can be explained by geometric and functional alterations seen with aging (18, 19). Studies in India, Nigeria, Zambia, United States and South Korea also showed similar results (10, 11, 20–22).

AKD was higher in males than in females. Among males, the mean average diameter of aortic knob was 3.14 ± 0.34 cm. Population based large cohort study in Netherlands showed that men had higher mean thoracic aorta diameter than women but provided no explanation as to why (23). Mean AKD findings in Indian population (20) and South Korean population (11) were comparable with our findings ($3.10 \text{ cm} \pm 0.334$ cm and 3.42 ± 0.478 respectively). The mean aortic knob diameter among females was 2.77 ± 0.37 . This value was smaller in comparison to the value obtained in the Indian (20) study of $3.076 \text{ cm} \pm 0.39$ cm and the south Korean (11) study of 3.00 ± 0.498 (Table 4).

Table 4
Comparison of aortic knob diameters in different populations

Authors	Country	Mean AKD/cm
Ray et al, 2014	India	Overall- 3.04cm±0.41 Male - 3.10cm±0.334 Female - 3.076±0.39cm
Felson, 1973	United states of America	3.0cm
Lee et al, 2018	South Korea	Mean overall -3.30±0.334 Males- 3.42±0.478cm Females -3.00±0.498cm
Rayner et al, 2004	United states of America	Normotensives -3.28cm Hypertensives -3.69cm
Magera et al, 2020	Uganda	Overall- 3.03±0.39cm Male- 3.14±0.34cm Female- 2.77±0.37cm.

The mean aortic knob and arch diameters were higher in males than females which is consistent with the findings of Ikeme and colleagues (24) and Ray and colleagues (20). On the contrary, a study done in Jamaica reported a higher aortic arch size in females than males (25). These findings were attributed to the higher blood pressures in females than males (25).

Kim and Choi observed that an aortic knob diameter (AKD) width of more than 4 cm occurred more frequently in patients with thoracic aortic disorder as compared to normal subjects (26). In this study, there was no female with an AKD > 4cm but there were 2 males whose AKD was slightly above 4cm measured on the digital screen. These were healthy males with no cardiovascular disease and normal blood pressure for age.

The AAD is another measurement for evaluation of the size of the aorta on chest radiograph (27). In this study the mean of the AAD was 5.6 ±0.64cm. This value is comparable to other values in different studies by Yousef and colleagues in Sudan (28) 5.3±0.6, and 5.3 by Umerah in Zambia (22). Anyanwu and Agwuna measured the width of the aortic shadow as the sum of the maximum extension of the aortic shadow to the right and left of the midline and found the mean of AAD varied between 4.7±0.5 cm in the Nigerian population (29).

The mean THD and mean TTD were 12.9±12.6 cm and 29.07±2.78cm respectively. This was comparable to 11.9 ± 9 cm of mean THD and 27.8± 7cm of mean TTD in the Sudanese population (28). This means,

our study population had higher mean of transverse heart and thoracic diameters. Aortic knob diameter correlated positively with chest and heart diameters in the Sudanese and Nigerian studies (21, 28).

In this study, we found that there was slightly higher mean AKD, when measurements done on a digital screen than on the x-ray films and the difference were statistically significant. This can be explained by the fact that digital measurements on screens are correct to the nearest millimeter, which may be difficult to achieve on the plain films due to approximation. Hence, measurements should be done on a digital screen than x-ray films in practice. This study also demonstrated that weight and height did not significantly affect the size of the aortic knob.

Strengths of our study include, being a prospective study with relatively large sample size and its multi-centric nature. The limitation of the study was that it was a hospital-based study which could introduce selection bias. Moreover, the number of female participants was much smaller than the male counterparts.

Conclusions And Recommendations

The aortic knob diameter was higher in males and there was a positive correlation with age, aortic arch diameter, transverse heart diameter and transverse thoracic diameter. We recommend aortic knob diameter measurements should be done on digital screen than printed x ray films and sex-specific aortic knob diameters should be utilized in clinical practice.

Abbreviations

AAD: Aortic arch diameter

AKD: Aortic knob diameter

THD: Transverse heart diameter

PA: Postero-anterior

TTD: Transverse thoracic diameter

Declarations

Ethics approval and consent to participate

Written informed consent was obtained from all participants to participate in the study. Ethical approval was obtained from Makerere University School of Medicine Research and Ethics committee (#REC REF 2019-107) and administrative clearance was sought from St Francis hospital, Case Hospital and Kिररुदु Hospital. All procedures of the study also followed the recommendation of the Declaration of Helsinki Convention.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contribution

All authors made significant contribution to the study by participating in its conception, study design, execution, acquisition of data, analysis and interpretation of the study results. The further all participated in the drafting, revising and critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Figures

The Aortic knob diameter is denoted by letter A
 The aortic arch diameter is denoted by letter B
 The transverse heart diameter is denoted by C+D.
 The transverse thoracic diameter is denoted by letter E.

Figure 1

Supplementary Files

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- [Appendix1.docx](#)