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Establishing the Cardiothoracic Ratio of Non-Hypertensive Patients Using Posteroanterior (PA) Chest Radiographs in an Indigenous Nigerian Population

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Abstract
Cardiothoracic ratio (CTR) is a simple, cheap and reproducible tool used as a classic index of cardiac size in screening for cardiovascular diseases. The study aims to establish the cardiothoracic ratio (CTR) of non-hypertensive patients using posteroanterior (PA) chest radiographs in an indigenous Nigerian population and correlate it with age and gender. This was a 12 months retrospective study of all the posteroanterior (PA) chest radiographs of 250 non-hypertensive patients retrieved from departmental archives of the Radiology department of the Benue state university Teaching Hospital (BSUTH), Makurdi from August 2018 to September 2019. The indication for the study as well as the patients` age, gender, and location were obtained. Measurements for maximum transverse cardiac diameter (MTCD)and the maximum internal thoracic width (MITW) were obtained and used to calculate the cardiothoracic ratio (CTR).Data was entered into statistical package for social science (SPSS) version 26 software for analysis, with the p value taken as <0.005. A total of 250 chest radiographs of non-hypertensive patients were used to assess the cardiothoracic ratio (CTR) in which 132(52.8%) were males and 118(47.2%) females. Routine medical check-up was the commonest indication, followed by peptic ulcer disease (PUD) in 126(50.4%) and 26(10.4%) patients who presented for chest X-rays respectively. In both cases, males were in the majority. The presumed "small heart" with a cardiothoracic ratio (CTR) less than 42%, was observed in a total of 29(11.6%) patients made up of 16 females and 13 males. Normal chest X rays (CXR) with a cardiothoracic ratio (CTR) between 42-50% was seen more in males than in females (111:100). "Borderline", but still abnormal cardiothoracic ratio (CTR) of between 51-55% was recorded for 10(4%) patients, while no patient presented with a cardiothoracic ratio (CTR) greater than 55%. The mean cardiothoracic ratio (CTR) increases steadily with age up to the 4th decade, with a lull at the 5th and then a slight spike after the 6th decade, with the males generally having greater values than the females. The mean cardiothoracic ratio (CTR) of the study population were 45.6%, 45.9% and45.3% for the general population, males and females respectively, with a statistically significant correlation (p=0.000) between male and female cardiothoracic ratio (CTR). The result of this study has established the cardiothoracic ratio (CTR) of indigenous Nigerian population in Makurdi as 45.6%.It has also shown the relationship between cardiothoracic ratio (CTR),and the patients` age and gender. These are necessary for comparison with similar findings elsewhere nationally and internally.

Keywords: *Cardiomegaly, Cardiothoracic ratio (CTR), Indigenous Nigerian, Maximum transverse cardiac diameter (MTCD), Maximum internal thoracic width (MITW), Radiography.*

Introduction

Worldwide, but most especially in the third World countries, chest radiography remains the most commonly used imaging modality for the evaluation of cardiothoracic ratio (CTR)and the assessment of cardiac size[1-3]. There are many methods for assessing the cardiac size on a plain chest radiograph, but the two most commonly used are by the measurement of the cardiothoracic ratio (CTR), and the maximum transverse cardiac diameter (MTCD).Heart size is usually measured on departmental postero- anterior (PA) chest radiographs. This is a common and non-invasive way to radiologically assess cardiac size for disease as well as in evaluating patient response to treatment [3-9].

The estimation of cardiac size with the use of chest radiographic images has been widely reported especially in developing countries[2, 4,10-13]. Easy availability, affordability and the simple nature of this means of assessing cardiac size and its changes over time have made chest radiograph the most common method despite improved imaging technology like computed tomography (CT Scan), magnetic resonance imaging (MRI), echocardiography, and angiography [1,6,8,14,15].

The alternative use of an anteroposterior (AP) radiograph for assessment of cardiac diameter is traditionally considered unsatisfactory. Strictly speaking, cardiothoracic ratio (CTR) should not be assessed on an anteroposterior (AP) radiograph. However, oftentimes due to limited mobility of very ill patients and the challenge with positioning them, portable anteroposterior chest radiograph (chest AP) is indicated in the emergency department (ED) or Intensive care unit (ICU). Chest anteroposterior (AP) radiograph has serious limitations preventing its use for the precise measurement of cardiothoracic ratio (CTR). These includes radiation entering through the anterior part of the chest which makes the cardiac diameter more magnified because the heart resides toward the anterior thorax; the shorter distance between the radiation source and the imaging cassette results in a larger image and thus overestimating both the cardiac and thoracic diameters; and for those patients who cannot inhale maximally or hold their breath because of dyspnea, pain, or unconsciousness; the thoracic diameter on AP radiograph is rendered unreliable[16,17].

Some Clinicians report cardiothoracic ratio (CTR) as a percentage (%), even though it is actually a ratio of the maximal horizontal cardiac diameter to the maximal horizontal thoracic diameter (inner edge of ribs/edge of pleura) at the level of the right diaphragmatic cupula. It is usual to express the ratio to two decimal places, e.g., 0.50, rather than 0.5. A normal cardiothoracic ratio (CTR) measurement is 0.42-0.50. A measurement <0.42 is usually deemed to be pathologic. A measurement >0.50 is usually taken to be abnormal although some radiologists feel that measurements of up to 0.55 are “borderline" [9]. This borderline figure (0.55) may still be considered normal for Blacks and Asians with the neonates and the elderly having a normal cardiothoracic ratio of up to 0.60 [4, 9]. A heart may be greater than 0.50 of the CTR but still be a normal heart. This can occur if there is an extracardiac cause of cardiac enlargement, due to inability to take a deep breath because of pregnancy, ascites or abnormalities of the chest that compress the heart such as pectus excavatum and straight back syndrome. Sometimes the heart can be smaller than 0.50 of the cardiothoracic ratio but still be an abnormal heart. This occurs when there is something obstructing the flow of blood from the ventricles since the ventricles respond at first by undergoing hypertrophy, which does not produce cardiomegaly[18].

Generally, an enlarged heart in respect of age, height, weight and body mass index (BMI) may give the first hint of underlying cardiac disease on routine chest X rays.[6, 11, 12.]

It is the authors` belief that local studies on Nigerian patients may help to define the cardiothoracic ratio (CTR) among our indigenous population. The use of inaccurate cardiothoracic ratio (CTR) and by extension maximum

transverse cardiac diameter (MTCD) values may result in delayed or unfounded diagnosis especially if used for referencing. Delay in treatment may occur when the reference values in use are misleading or significantly different from the actual local values recorded. Unjustifiable medication may be administered in circumstances when actual local values are unavailable [4].

This study is aimed at establishing the cardiothoracic ratio (CTR) of non-hypertensive patients using posteroanterior (PA) chest radiographs in an indigenous Nigerian population. The study will also examine if other parameters such as age and gender of subjects have any relationship to the cardiothoracic ratio (CTR).

Materials and Methods

This was a retrospective study conducted at the Radiology Department of the Benue State University Teaching Hospital (BSUTH), Makurdi from August 2018 to September 2019. Makurdi town is the state capital of Benue state located in the North central region of Nigeria. The state teaching hospital (BSUTH) serves as a referral center for the state and other surrounding states in the country.

Posteroanterior (PA) chest radiographs of a total of 250 indigenous Nigerians bearing a typical Nigerian name signifying that the patient has at least one Nigerian parent were evaluated during the study period. The radiographs were retrieved from departmental archives after necessary approval that met the inclusion criteria. Information sought for, included indication for the study, patients' location, age, and gender.

Inclusion Criteria

i. Chest radiograph of indigenous non-hypertensive Nigerians bearing a typical Nigerian name signifying he/she has at least one Nigerian parent
ii. Non-hypertensive patient who had undergone chest x-ray at the Radiology unit of Benue State University Teaching Hospital (BSUTH) Makurdi
iii. Patients with no underlying cardiovascular clinical symptoms
iv. Patients aged 18 years and above

Exclusion Criteria

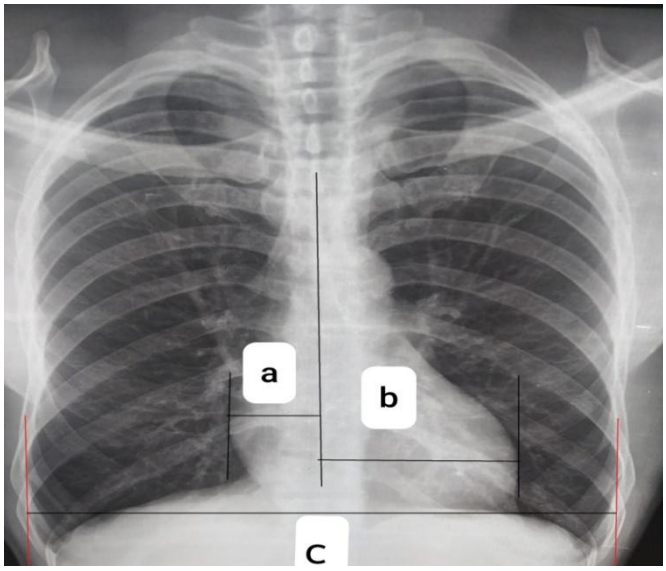
i. All patients outside the inclusion criteria
ii. Technically unsatisfactory radiographs, like the inability to identify one or both cardiac borders (silhouette sign), significant mediastinal shift and severe rotation
iii. Patients with thoracic or spinal deformity

The research made use of the clinician's provisional diagnosis on the request form to disqualify patients with cardiac or chest problems as well as patients whose chest radiograph shows cardiac or thoracic cage abnormality. This was done to reduce the probability of using radiographs of clients/patients with cardiac problems and/or abnormalities.

Radiographic examination was performed with Philips medical system X-rays machine DNCGMBH-Roentgestrabe 24 D 22335 (Hamburg/Germany) with AGFA medical system digitizer, Equipment ID 10261788 and Daystar 5503 AGFA printer. The patients were rehearsed on breathing technique (deep and arrested inspiration). They were asked to "wear up" long hair and to remove any radio-opaque objects, including jewelries around the chest region capable of affecting the diagnostic quality of the image prior to their positioning and before the X-rays exposure while wearing an examination gown. Patient were positioned erect facing the upright image receptor, the superior aspect of which was about 5 cm above the shoulder joints, with the chin raised and shoulders rotated anteriorly to allow the scapulae to move laterally off the lung fields. A well collimated horizontal X-rays beam was centered at the level of the 7^{th} thoracic vertebra, approximately the inferior angle of the scapulae while exposures were made at normal, quiet arrested inspiration. All radiographs were acquired with the participant in the erect PA position at a film focus distance of 180 cm. The radiographic measurements with a

ruler under optimum viewing condition included the maximum transverse cardiac diameter (MTCD) and the maximum internal thoracic width (MITW). The MTCD was obtained by measuring the horizontal distance between the most rightwards and leftwards borders of the heart as seen on the chest radiograph, whereas the MITW was measured as the horizontal distance inside the rib at the widest point above the costophrenic angles as seen on the PA chest radiograph [Figure 1].

Figure 1: PA chest radiograph in an adult demonstrating how to measure maximum transverse cardiac diameter (MTCD) and maximum internal thoracic width (MITW)



Other information including age, gender, MTCD, MITW and CTR were entered into statistical package for social science (SPSS) version 26 software for analysis. Tables were generated for grouped data. Mean, standard deviation, and confidence interval (95%) of CTR, MTCD, and MITW were equally generated for continuous variables. Chi-squares, used to test the goodness of fit were used to show the proportion of gender distribution. Correlations were used to test the relationship between age, gender, MTCD, MITW and CTR.*P*-values<or equal to 0.005 was considered significant for the study.

These measurements were used to calculate the CTR as follows:

$$CTR = \frac{MTCD}{MITW} \times 100\%$$

$$CTR = \frac{a\ (MRD) + b\ (MLD)}{c\ (ID)} \times 100\%$$

Where: a (MRD) = perpendicular Most Rightwards Diameter of heart

b (MLD)= perpendicular Most Leftwards Diameter of heart

c (ID)= Internal Diameter of chest at the level of the right hemidiaphragm

Results

A total of 250 radiographs of indigenous Nigerians were evaluated for the study out of which 132 (52.8%) were males and 118(47.2%) females as shown in figure 1. The participants' age spans from 18yrs to 78yrs with a mean age of 22.46 years±13.46 (Figure 2).

The presumed "small heart" with a cardiothoracic ratio (CTR) less than 42%, was observed in a total of 29(11.6%) patients made up of 16 females and 13 males. Normal chest X rays (CXR) with a cardiothoracic ratio (CTR) between 42-50% was seen more in males than in females (111:100). "Borderline", but still abnormal cardiothoracic ratio (CTR) between 51-55% was recorded for 10(4.0%) patients, while no patients presented with a cardiothoracic ratio (CTR) greater than 55%. Table1 &2 below.

Table 3 shows the study population which was further divided into age Groups, according to gender. The mean CTR of each of these groups using a 95% confidence interval was obtained.

The mean CTR of all the subjects (general) and males of all the age groups was less than 50%. The mean CTR for females less than 68 years was less than 50% while that for females aged 69 years or more was 50.0 ± 0.00%. The mean CTR of the study population were 45.6% (SD- 0.036; margin of Error for 95% Confidence Interval (ME)- 0.002), 45.9% (SD-0.036, ME- 0.003) and 45.3% (SD-0.037, ME- 0.003) for the general population,

males and females respectively. The mean CTR increased gradually with age up to the 4th decade, with males generally having greater values than females as shown in table 3.

Table 4 depicts a summary of the mean MTCD, MITW and CTR for the study population, which is 10.56cm, 23.08cm and 45.6% respectively.

There is a statistically significant correlation (*p*=0.000) between male and female CTR as depicted in table 5. The mean MTCD of the males is significantly higher than the females (*p*=0.000). A statistically insignificant correlation (*p*=0.270) exists between the MITW of males and females.

Table 6 shows that the mean CTR value for the general population correlated well with the participants` ages (*p*=0.000). The CTR increases steadily with the age up to the 4th decade with a lull at the 5th and then a slight spike after the 6th decade

Figure 1: Gender distribution

Figure 2: Age Distribution

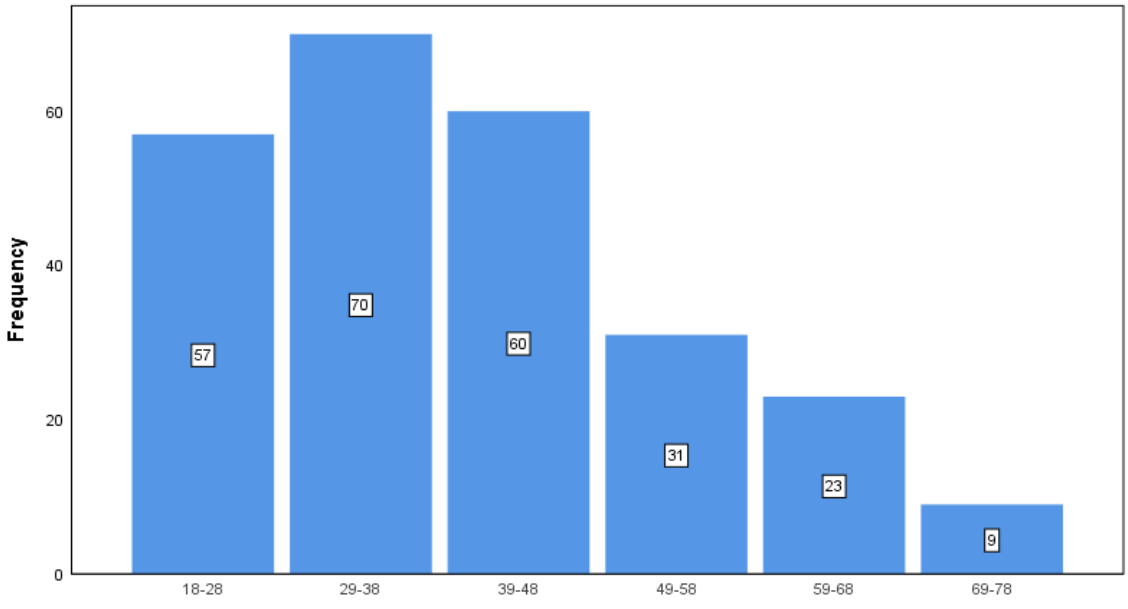


Table 1: CTR Distribution

CTR(%)	Frequency	Percent	Cumulative Percent
<42	29	11.6	11.6
42-50	211	84.4	96.0
51-55	10	4.0	100.0
Total	250	100.0	

Table 2: Distribution of Gender with CTR

		CTR (%)			
		<42	42-50	51-55	Total
Gender	M	13	111	8	132
	F	16	100	2	118
Total		29	211	10	250

Table 3: Distribution of Age groups according to Gender with CTR

Gender	**Age (Yrs)**	**Mean (CTR)**	**N**	**Std. Deviation**	**Std. Error of Mean**	**CI (*95%*)**
M	18-28	.4440	35	.03098	.00524	0.444 ± 0.005
	29-38	.4553	32	.03707	.00655	0.455±0.006
	39-48	.4621	28	.03625	.00685	0.462±0.007
	49-58	.4586	14	.03394	.00907	0.459±0.009
	59-68	.4847	15	.03314	.00856	0.485±0.008
	69-78	.4725	8	.02659	.00940	0.473±0.009
	Total	.4585	132	.03559	.00310	0.459±0.003
F	18-28	.4405	22	.04029	.00859	0.441±0.009
	29-38	.4484	38	.03767	.00611	0.448±0.006
	39-48	.4619	32	.03031	.00536	0.462±0.005
	49-58	.4594	17	.04279	.01038	0.459±0.01
	59-68	.4563	8	.02387	.00844	0.456±0.08
	69-78	.5000	1	.	.	0.500±0.00
	Total	.4531	118	.03676	.00338	0.453±0.003
∑ (M+F)	18-28	.4426	57	.03456	.00458	0.443±0.005
	29-38	.4516	70	.03729	.00446	0.452±0.004
	39-48	.4620	60	.03293	.00425	0.462±0.004
	49-58	.4590	31	.03841	.00690	0.459±0.007
	59-68	.4748	23	.03273	.00683	0.475±0.007
	69-78	.4756	9	.02651	.00884	0.476±0.009
	Total	.4560	250	.03617	.00229	0.456±0.002

Table 4: Mean MTCD, MITW and CTR of the study population

VARIABLE	MEAN±SD	MINIMUM	MAXIMUM
MTCD (cm)	10.56±0.02	11.00	23.00
MITW (cm)	23.08±0.01	19.30	29.50
CTR (%)	45.6±0.04	34.00	54.00

Table 5: Distribution of Gender with mean MTCD, MITW, and CTR

GENDER	MTCD (cm)	MITW (cm)	CTR (%)
MALE	10.69±2.52	23.21±2.12	45.85±.0.04
FEMALE	10.42±1.32	22.94±1.85	45.31±0.04
p	0.000	0.270	0.000

Table 6: Distribution of Age groups with mean MTCD, MITW, CTR

Age group	n	MTCD (cm)	MITW (cm)	CTR (%)
18-28	57	23.48±1.52	30.59±2.23	44.3±0.03
29-38	70	19.09±1.68	20.95±2.46	45.2±0.04
39-48	60	26.68±1.70	22.32±2.31	46.2±0.03
49-58	31	31.63±1.89	36.66±2.67	45.9±0.04
59-68	23	24.66±1.43	18.64±2.10	47.5±0.03
69-78	9	18.53±1.27	08.00±1.99	47.6±0.03
p		0.000	0.000	0.000

Discussion

Cardiothoracic ratio (CTR) is a very simple measurement and calculation. It is also a useful tool which can serve as a classic index of cardiac size in screening for cardiovascular diseases. But its value has been questioned over the years because echocardiography, radionuclide imaging, angiography, computed tomography (CT), and magnetic resonance imaging can provide more precise information about cardiac function[2,8,16].

However, in our resource-poor developing countries, the relevance and importance of cardiothoracic ratio (CTR) measurement on chest radiograph cannot be over-emphasized and is apparent not only in the evaluation of the patient at the first contact but also becomes increasingly important during the subsequent follow-up assessment of the patient. When the normal value of CTR for the local population is known, the status of the patient`s heart can easily be assessed with lifesaving timely intervention in the emergency department (ED) or intensive care unit (ICU)[2,5,8,16].

The mean cardiothoracic ratios (CTR) of our study population were 45.6%±0.00, 45.9%±0.00, 45.3±0.00 for the general population, males and females respectively. This result compared favorably with similar studies in Ghana, the Kingdom of Saudi Arabia (KSA)**,** and Maiduguri (Nigeria). The mean cardiothoracic ratio (CTR)values were45.9%±0.20, 45.2%±0.20 and 46.7±0.20respectively for the general population, males, and females in a study by Mensah YB et al[2] in Ghana. In the Kingdom of Saudi Arabia (KSA)**,** 46.03%± 0.04, 45.2%±0.04, 47.2%±0.04 were similarly reported in a study by Moawia et el[5]. In Maiduguri (Nigeria) the mean cardiothoracic ratios (CTR) reported by Modu A et al[8] were 45.60%, 45.10%, 45.71% respectively for the general population, males, and females. The slightly higher mean cardiothoracic ratio (CTR) values in females as against men in these studies[2,5,8] is noticeably in sharp contrast to our study which reported slightly higher mean cardiothoracic ratio (CTR) in men. The disparity in our case, can be explained by the fact that men are usually involved in more physically demanding activities than women, apart from the inherent influence of hormones in both sexes (sexual dimorphism)[13,19]. There was also a statistically significant correlation (*p*=0.000) between male and female cardiothoracic ratio (CTR) in our study.

The mean cardiothoracic ratio CTR increased steadily with age up to the 4th decade, with a lull at the 5th and then a slight spike after the 6th decade in the present study, a finding variably documented in other reports[2,5,13,19]. The increase in cardiothoracic ratio (CTR) with age, particularly in women was mainly due to contraction of the thoracic diameter rather than an increase in cardiac diameter[13]. In our study the mean cardiothoracic ratio (CTR) value for the general population correlated well with the age of participants *(p*=0.000). The influence of age on cardiac size is demonstrated by a more gradual increase in cardiothoracic ratio (CTR) after the 5thdecade. This is because at this stage of life, occult cardiovascular disease (CVD), in addition to myocardial and vascular changes interact with the persistent cohort phenomenon to confound the change of heart size with age[19].

The maximum transverse cardiac diameter (MTCD) in our study was higher in male than female (10.69±2.52>10.42±1.32) with a statistically significant correlation (p=0.000). This finding is corroborated by earlier reports[2,5,8]. The trend was also noted in other studies that have been done on Caucasians, Asians and people of African descent[2,20].The increase in transverse cardiac diameter with age has been attributed to increased cardiac ventricular muscle thickness resulting from increased vascular resistance or loss of elasticity of the great vessels[2].Our study also shows that the maximum transverse cardiac diameter (MTCD) was relatively stable up to the 4th decade with a sudden spike at the 5th decade, and gradually decreasing thereafter. This is in sharp contrast to the findings by Modu A et al[8,] which reported no increase in maximum transverse cardiac diameter (MTCD) with age.

This study noted a statistically insignificant correlation (p=0.270) between mean maximum internal thoracic width (MITW) of males and females (23.21±2.12>22.94±1.85). There was also a steady decrease in the mean maximum internal thoracic width (MITW) value with age till the 3rd decade, increasing from the 4th-5th decade and sharply decreasing after this. The reduction in the mean maximum internal thoracic width (MITW) has been attributed to reduced ribcage mobility and compliance in the elderly[2,8].

The present study had its own limitations in that chest radiographs of apparently healthy clients/patients were used. But as noted in our findings, the non-existence of symptoms does not automatically imply the absence of infirmity.

Conclusion

We have established 45.6% as the mean CTR value for the indigenous Nigerian population in Makurdi. The relationship between age and gender with the patient's cardiothoracic ratio (CTR), has also been noted. These reports compare favorably with findings of similar studies nationally and internationally. The values will be very useful in screening our indigenous population for cardiomegaly.

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Conflicts of Interest: There are no conflicts of interest.

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