Original Research Article

RADIOGRAPHIC STUDY OF VARIATION IN DIAPHRAGM POSITION OF ADULT NIGERIANS

ABSTRACT

Variation is constant in humans. This research work was carried out to study the variation in the diaphragm position of adult Nigerians using normal PA chest radiographs. A total of 500 samples (298 females and 202 males), obtained from the Radiology Department of the University of Port Harcourt Teaching Hospital were used. The variation in the diaphragm position was measured relative to the following anatomic land marks; thoracic vertebra, crossing rib and lung height. For descriptive analysis SPSS version 24 software package *was used, and Z- test to test for significance. This study showed that the variation of diaphragm position in adult Nigerians was statistically significant (p<0.05) and the diaphragm position of females was higher than males. These findings will be very useful to the cardiothoracic surgeons, radiologist and the clinical anatomist.*

Key words: Variation, diaphragm, radiograph and crossing rib.

INTRODUCTION

Human beings all over the world, though being of the same species (Homo sapiens), differ from each other in some aspect. These differences, which make two individuals, even identical (monozygotic) twins, not to be the same, constitute variation. Krishan [1] also noted this, when he stated “No two individuals are exactly alike in all their measurable traits.”

Hence, variation is the distinctive characteristics or features, that an individual possesses which makes him/her different from another individual. It can be seen among individuals of the same/different gender, race, age, etc, and may be as a result of differences in the genetic make-up of humans, due to adaptation to varying environmental conditions or due to mutation, etc [2].

Radiology has given valuable information about the shape, position and movements of the diaphragm in the living subject. In an anterior view of the thorax, the diaphragm is seen to consist of right and left domes, separated by a central portion which is obscured by the heart and vertebral shadows [3].

Over recent years, the importance of assessing diaphragm structure and function in critically ill patients has increasingly been recognized [4] [5]. Diaphragm position and shape on chest radiographs are routinely used as indicators of normal and abnormal pulmonary function, but much work has not been done to determine the variation in diaphragm position that may occur in normal healthy individuals. This perhaps, may be due to the fact that more attention is concentrated on the skeletal structures and some other organs and structures, perceived to be more important. Assessment of muscular thickness and thickening fraction during respiration have been used to assess loss of muscle mass and muscle function, respectively, although the latter remains controversial [6].

However, some have recognized the importance of the diaphragm, a renowned one being Andrew Taylor Still, the founder of Osteopathy, who emphasized the importance of the structure and function of the diaphragm, and even tried to speak for it thus: By me you live and by me you die, I hold in my hands the power of life and death, and stated that "All parts of the body have direct or indirect connection with the diaphragm" [7].

In realization of this importance, some research work has been done in some countries concerning the diaphragm, though not much in terms of variation of its position. Various studies have been conducted on the diaphragm, though few on the variation of its position.

A study done by Suwatanapongched et al., [8] on diaphragm position and shape of one hundred and fifty-three adults, in the United States of America showed that there was substantial variability in diaphragm position and shape, in relation to weight, age and thoracic dimension. This study revealed that diaphragm position among the individuals was lower with increasing age, especially when using age quartiles and deciles. For the transverse thoracic diameter, the diaphragm position was seen to be lower with narrow transverse diameter (i.e. the narrower the transverse diameter, the lower the diaphragm position).

Chetta, [9], on studying the chest-radiographs of 42 (17 female age range 22-79 years) patients who underwent phrenic nerve stimulation, observed that there was isolated deviation of hemidiaphragm on chest radiographs (24 % for patient with unilateral paralysis), though the little value in the diagnosis of unilateral hemidiaphragm paralysis. That is to say that there is deviation from normalcy when there is paralysis, though not stated by him.

Gorman et al., [10], on studying severe chronic obstructive pulmonary disease (COPD), using 10 patients with COPD and 10 normal persons of the same age and sex, stated that patients with severe COPD, had marked reduction in the length of the diaphragm in the coronary plane at both functional residual capacity and residual volume when compared with the matched subject.

Bellemare et al., [11] during their study of sex differences in thoracic dimensions and configuration using 40 normal subject (21 male and 19 female), noted that diaphragm dome position relative to spine. in females, at all lung volumes examined was comparable whereas the diaphragm length was shorter than males of the same height.

Grosu et al., [12] were the first to prospectively measure diaphragm thickness using ultrasound imaging during invasive ventilation. Diaphragm thickness decreased at an average rate of 6% per day suggesting development and a rapid progression of diaphragm atrophy. The results have been extended by Zambon et al., [13] who measured diaphragm thickness daily, from the first day of mechanical ventilation until ICU discharge in 40 patients on various levels of ventilator support. The mean daily decrease in diaphragm thickness seemingly was more pronounced with increasing levels of ventilatory support. The results must be interpreted with great caution as the level of ventilator support was only marginally correlated with daily rate of diaphragm atrophy ($r2=0.14$, $p=0.006$). When examining the daily change in diaphragm thickness of individual patients in the study of Zambon et al., it is apparent that some patients experienced a decrease in diaphragm thickness while others experienced no change or even an increase in thickness. Similar results have been reported by Schepens et al., [14] in 54 ventilated patients. Compared to baseline, the last recorded value of thickness before extubation, tracheotomy or death had decreased in 40 (77%) patients, it was unchanged in ten (19%) patients and it had increased in two (4%) patients.

Variability in the change of diaphragm thickness was reported also in a study of more than 200 ventilated patients cared for in three Canadian ICUs [15]. Forty percent of patients developed a decrease in diaphragm thickness by day 4 of ventilation. This decrease was associated with a lower probability of weaning success and increased risk of complications (reintubation, tracheostomy, prolonged ventilation). A quarter of the patients exhibited an increase in diaphragm thickness over the first several days of ventilation. The patients were also less successful in weaning and had an increased risk of reintubation. The remaining 35% of patients experienced less than 10% change in diaphragm thickness. This last group had a greater probability of weaning success and fewer complications than the other two groups. The risk of death was similar in the three groups of patients. The investigators concluded that development of either progressive decrease or progressive increase in diaphragm thickness during the early course of mechanical ventilation increases the risk of complications and predicts prolonged ventilation. The latter conclusion, however, should be interpreted with caution as the weaning strategy and use of rescue noninvasive ventilation after extubation in the ICUs were not standardized. The study also underscores a potential limitation of cross-sectional investigations of diaphragm thickness in critically ill patients. Moreover, it seriously puts into question the existence of a linear relationship between diaphragm thickness and the number (and function) of diaphragm contractile elements in these patients [16] [17]. The absence of such a relationship and, thus, the absent relationship between diaphragm thickness and clinical outcomes, is supported by the data of Dubé et al. [18], Vivier et al. [19], and Grosu et al. [20].

Haaksma et al. [21], in a study evaluated the variability of diaphragm thickness assessed by ultrasound in healthy adult volunteers, their main findings were that craniocaudal variability in diaphragm thickness was lowest on the midaxillary line, midaxillary thickness is comparable to posterior axillary thickness, while midclavicular thickness is significantly higher.

This study is aimed at adding to the available literature on diaphragm position, and to determine the variation in the diaphragm position among adult Nigerians, using radiographs. The study is relevant to the anatomist, radiologist, pulmonologists, as well as cardiothoracic surgeons.

MATERIALS AND METHODS

A retrospective study was done on 500 normal posteroanterior (PA) chest radiographs of adult Nigerians, between the ages of 20 and 70 years. Random sampling method was used to obtain the normal posteroanterior (PA) chest radiographs (of which 298 were that of females and 202 that of males) from the Radiology Department of the University of Port Harcourt Teaching Hospital. The following criteria, with the help of a radiologist were used to select the normal radiographs: Thoracic cage is intact; No thoracic vertebra and rib fracture; Lung fields are clear and no focal lesion seen; No hyperinflation or inadequate inspiration, but normal deep inspiration; Cardiac silhouette is normal.

From the information obtained along with the radiographs, the radiographs were that of subjects from northern, southern, western and eastern Nigeria, though those of the northerners were not much when compared to the rest.

Using a meter rule and a pencil, the following measurements were taken from the radiographs with the aid of the x-ray viewing box: Diaphragm position (relative to thoracic vertebral length, crossing rib level and lung height) and maximum transverse thoracic diameter.

MEASUREMENT OF DIAPHRAGM POSITION RELATIVE TO THORACIC VERTEBRAL LENGTH (TVL):

This measurement was done by drawing a horizontal line tangential to the dome of the hemidiaphragm, this line was made to cross the thoracic vertebra. Then with the superior end plate of the first thoracic vertebra taken as the 'starting point' of measurement, a meter rule was used to measure the vertical distance from the superior end plate of the thoracic vertebrae to the tangential line that was earlier drawn from the hemidiaphragm dome to meet the thoracic vertebra. This was done for the two hemidiaphragms (right and left) of each and every chest radiograph used.

MEASUREMENT OF DIAPHRAGM POSITION RELATIVE TO CROSSING RIB LEVEL (CRL):

This was determined as the vertical distance between a horizontal line drawn through the midpoint of the intersecting shadows of the anterior sixth and posterior tenth ribs, and the horizontal line drawn tangential to the hemidiaphragm dome. If the dome was positioned above the crossing rib level, the result was assigned a negative value.

MEASUREMENT OF MAXIMUM TRANSVERSE THORACIC DIAMETER (MTTD):

The maximum transverse thoracic diameter was measured as the greatest horizontal distance, between the inner margins of the corresponding level of the rib cage. The method of measuring the diaphragm position relative to the crossing rib level (CRL), the lung height (LH) and the maximum transverse thoracic diameter has been previously applied by Suwantanapongched et al. [8].

MEASUREMENT OF DIAPHRAGM POSITION RELATIVE LUNG HEIGHT (LH):

The height of the lungs (LH) was used as another indicator of the diaphragm position. It was measured from the inferior margin of the second rib to the horizontal line drawn tangential to the dome of the hemidiaphragm.

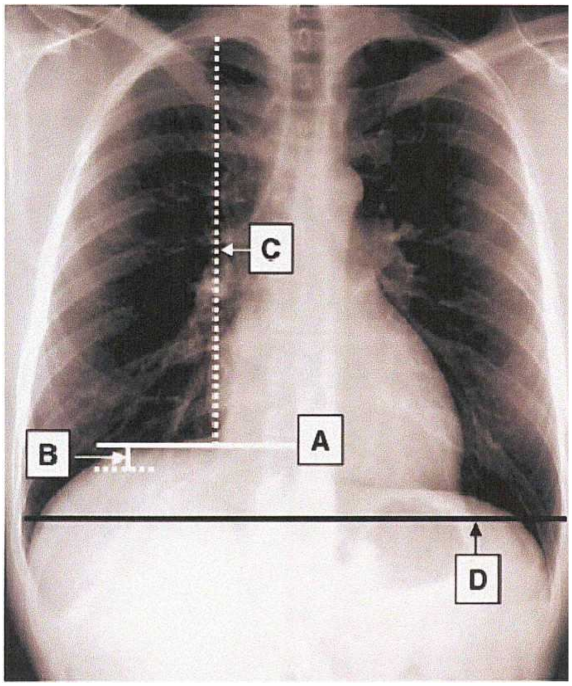

Figure 1. Posteroanterior radiograph showing measurements for right TVL, right CRL, right LH and maximum transverse thoracic diameter. A _ right hemidiaphragm position relative to thoracic vertebral length; B _ right hemidiaphragm position relative to crossing rib level; C _ right lung height; D _ MTTD. Horizontal solid white line is the line drawn tangent to the top of the right hemidiaphragm dome. Horizontal dotted white line is the line drawn through the midpoint of intersecting shadows of the anterior sixth and posterior tenth ribs.

RESULT AND ANALYSIS

A descriptive analysis was carried out on these parameters using the SPSS version 16 software package, while the test for significance was done using Z-test. The mean, standard deviation and standard error of the measured parameters were compared between males and females and presented in tables 1 and 2. The descriptive statistics of the measured parameters according to age groups are presented in tables 3, 4 and 5, while table 6 presents the test for significance of the measured parameters.

Table 1: Descriptive Statistics of measured parameters of males and females

Gender	Parameters (cm)	N	Minimum	Maximum	Mean		Std. Deviation
		Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
	RTVL	202	17.60	30.60	23.33	±0.14	±1.97
	LTVL	202	19.40	31.70	24.83	±0.14	±2.05
	RLH	202	15.40	27.90	21.23	±0.14	±1.93
MALE	LLH	202	16.90	29.10	22.76	±0.15	±2.07

	MTTD	202	23.40	34.00	28.97	±0.15	±2.08
FEMALE	RTVL	298	14.80	25.80	20.98	±0.12	±1.99
	LTVL	298	15.70	28.00	22.23	±0.12	±2.14
	RLH	298	13.90	24.00	19.21	±0.11	±1.92
	LLH	298	14.90	26.00	20.50	±0.12	±2.05
	MTTD	298	22.10	32.40	26.35	±0.11	±1.87

Table 2: Descriptive Statistics of crossing rib level of males and females

Gender	Parameters (cm)	N	Mean	Std. Deviation	Frequency of-CRL		
		Statistic	Statistic	Statistic	BOTH	RT	LT
MALES	RCRL	202	1.54	±1.04	43	53	4
	LCRL	202	2.03	±1.28			
FEMALES	RCRL	298	1.63	±1.20	118	58	5
	LCRL	298	1.70	±1.15			

Table 3: Descriptive Statistics of measured parameters for age groups of males and females

GENDER	PARAMETERS (cm)	20-29		30-39		40-49		50-59		>60	
		MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
MALE	N	43		29		15		5		9	
	RTVL	23.33	±1.81	22.76	±2.22	22.95	±2.15	23.14	±2.11	23.98	±2.00
	LTVL	24.78	±1.99	24.21	±2.36	24.24	±2.20	24.50	±2.03	25.92	±1.74
	RLH	21.13	±1.85	20.71	±2.32	20.77	±1.96	20.74	±1.79	21.58	±1.66
	LLH	22.82	±1.93	22.17	±2.46	21.83	±2.07	22.34	±1.83	23.61	±1.71
	MTTD	28.87	±2.13	29.92	±1.78	28.68	±2.06	28.54	±2.57	28.66	±0.96
FEMALE	N	51		29		18		12		10	
	RTVL	20.93	±2.18	21.16	±1.62	21.51	±2.04	21.73	±2.07	21.14	±2.98
	LTVL	22.39	±2.29	22.30	±1.74	22.84	±2.53	22.70	±2.07	22.87	±2.75
	RLH	19.30	±2.09	19.30	±1.59	19.79	±2.07	20.01	±1.85	19.44	±2.60
	LLH	20.74	±2.26	20.55	±1.56	21.29	±2.45	21.04	±1.93	20.73	±2.59
	MTTD	26.08	±1.84	27.75	±2.16	26.96	±2.03	27.18	±1.57	26.37	±1.95

Table 4: Descriptive Statistics of crossing rib level for each age group of males

AGE	SIDE	N	Mean	Std. Deviation	Frequency of -CRL		
		Statistic	Statistic	Statistic	BOTH	RT	LT
20-29	RT	43	1.41	±1.03	10	10	1
	LT	43	1.86	±1.17			
30-39	RT	29	2.02	±1.21	12	5	0
	LT	29	2.23	±1.51			
40-49	RT	15	1.51	±0.69	4	3	0
	LT	15	1.79	±1.13			
50-59	RT	5	1.52	±0.76	0	2	0
	LT	5	2.08	±1.91			
>60	RT	9	1.92	±1.36	1	2	0
	LT	9	2.93	±1.50			

Table 5: Descriptive Statistics of crossing rib level for each age group of females

AGE	SIDE	N	Mean	Std. Deviation	Frequency of -CRL		
		Statistic	Statistic	Statistic	BOTH	RT	LT
20-29	RT	51	1.91	±1.34	20	13	1
	LT	51	1.87	±1.44			
30-39	RT	29	1.51	±1.07	14	3	1
	LT	29	1.78	±1.05			
40-49	RT	18	1.37	±1.10	5	2	0
	LT	18	2.01	±1.17			
50-59	RT	12	1.37	±0.91	1	2	0
	LT	12	1.69	±0.92			
≥60	RT	10	2.39	±1.88	4	2	0
	LT	10	2.30	±1.31			

Table 6: Test for significance of parameters for males and females

Parameter	Gender	N	Mean	SD	Z-cal.	P-value ($p < 0.05$)	Inference
RTVL	Male	202	23.33	±1.97	13.06	1.96	Significant
	Female	298	20.98	±1.99			
LTVL	Male	202	24.83	±2.05	13.68	1.96	Significant
	Female	298	22.23	±2.14			
RLH	Male	202	21.23	±1.93	11.54	1.96	Significant

	Female	298	19.21	±1.92			
LLH	Male	202	22.76	±2.07	12.02	1.96	Significant
	Female	298	20.50	±2.05			
MTTD	Male	202	28.97	±2.08	14.40	1.96	Significant
	Female	298	26.35	±1.87			
	Female	298	12.60	±1.36			
RCRL	Male	202	1.54	±1.04	0.88	1.96	Not significant
	Female	298	1.63	±1.20			
LCRL	Male	202	2.03	±1.28	2.95	196.00	Significant
	Female	298	1.70	±1.15			

DISCUSSION

Analysis of the data obtained from the measured parameters of the chest radiographs of adult Nigerians between the ages 20-70 years, showed that there is statistically significant variation in diaphragm position of adult Nigerians. This is in line with previous studies by Suwatanapongched et al., [8] in the United States of America, who noted that there is substantial variability in diaphragm position.

It is also in line with the works of Lennon and Simon [22] and Stewart and Illick [23], who in their different researches done on the diaphragm, also noted the variation in the position of the diaphragm.

From the present study, the variation in the diaphragm position of the individuals of the same and different gender. The right hemidiaphragm dome position was 1 to 2cm higher than the left in both genders, and is in line with the known anatomic descriptive level of the right and left hemidiaphragm domes [3].

The diaphragm position of the females tends to be higher than that of the males in this study, just as noted in the previous study by Suwatanapongched et al., [8].

In this study also, the position of the diaphragm tends to be higher in individuals with smaller thoracic diameter and vice versa, as also noted by Suwatanapongched et al., [8]. And it is observed here that the maximum tranverse diameter of the females is smaller than that of the males, 26.4 ±1.9 and 29.0 ± 2.1, respectively, and as earlier mentioned above, the females had their diaphragm position higher than males; this may therefore show that diaphragm position is perhaps dependent on the maximum transverse thoracic diameter.

In analyzing the position of the diaphragm based on the age groups in this study, it was found that the position of the diaphragm was not actually high or lower with increasing or decreasing age, though Suwatanapongched et al. [8], noted a weak correlation in their study, stating that the diaphragm position was low with increasing age.

From this study, it could be concluded that there is variation in the diaphragm position of adult Nigerians and that the position of the diaphragm position tends to be dependent on the maximum transverse thoracic diameter of the individual.

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