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Original Article

Revisiting anatomical variants on screening chest radiographs in Indian adolescents: A cross sectional observational pilot study

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ABSTRACT

Background: Knowledge of normal variation and measurements on a chest radiograph is essential to interpret any abnormality. There is paucity of information about normal measurement ranges and variations in young adolescents, particularly from Indian sub-continent. The aim of this study was to analyze certain normal variations on screening chest radiographs of healthy Indian adolescents and the objectives were to measure/assess (1) degree of inspiration, (2) cardiothoracic ratio (CTR), (3) presence of gastric fundic bubble, (4) fundocupolic distance, (5) presence of splenic flexure, (6) difference in height of diaphragmatic domes and (7) effect of inspiration on the CTR.

Methods: Digital chest radiographs obtained during routine medical examinations for all consecutive medical graduate aspirants in the year 2016 at a medical college, were analyzed for the above mentioned parameters using DICOM viewing software.

Result: A total of 558 chest radiographs were analyzed. The mean age of the subjects was 18.50 (SD = 1.002) (range: 17–22 years). There were 497 (89.1%) male and 61 (10.9%) female. Degree of inspiration was at 5th, 6th, 7th and 8th ribs in 29 (5.1%), 259 (46.4%), 264 (47.3%) and 6 (1%) respectively. Mean maximum transverse cardiac diameter, internal thoracic diameter, CTR were 1153.22 ± 120.01 , 2935.24 ± 224.86 and 0.39 ± 0.03 respectively. Females had slightly higher CTR (0.40 ± 0.035) as compared to the males (0.39 ± 0.032) ($p = 0.009$). Gastric fundic bubble was visualized in 91% subjects. Mean fundo-cupolic distance was 8.75 ± 8.00 . Mean value for difference in the level of two domes of diaphragm was 15.28 ± 5.38 .

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Conclusion: The study highlights normal range of inspiration, CT ratio, fundocupolic distance and diaphragmatic dome level difference on screening chest radiographs in healthy Indian adolescents.

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Introduction

Chest radiographs form one of the most commonly performed radiological investigations in the diagnostic work up of patients in any health care setting. Despite tremendous advancements in the field of radiology and imaging, chest radiographs have retained their importance in the evaluation of respiratory and cardiovascular pathologies even today.¹ Chest radiographs often form an important component of screening medical examination before entry into various institutions/organizations particularly training establishments in India. Physicians are expected to be aware of the interpretation of basic findings in a chest radiograph. Suffice to say that one needs to be familiar with the normal appearances, sizes/measurements and variations in a chest radiograph before interpreting and diagnosing abnormal chest radiographs. Although the upper limit of cardiothoracic ratio (CTR) has been defined as 50%, there is paucity of literature regarding normal cardiac size and normal CTR especially for different ethnic/geographic regions.² Similarly, literature is scant about degree of inspiration, level of domes of diaphragms and assessment of gastric fundic bubble which also plays an important role in the assessment of chest radiograph besides lung fields and mediastinal structures. With the widespread availability of computed and digital radiography, it is now possible to obtain better quality radiographs than before. Also, DICOM viewing software enables accurate measurements of various structures with high degree of accuracy and ease. To the best of our knowledge, there is no data available for normal values/findings on chest radiographs for Indian young adults. The present study was carried out to evaluate certain normal ranges/variations on screening chest radiographs of apparently healthy Indian young adults with an aim to analyze certain normal findings and variations on screening chest radiographs of healthy Indian young adults.

Objectives

(1) To measure degree of inspiration, (2) to measure cardiothoracic ratio, (3) to assess presence/absence of gastric fundic bubble, its morphology and fundo-cupolic distance, (4) to assess presence/absence of splenic flexure shadow and its effect on the gastric bubble if any, (5) to measure relative positions of domes of diaphragms and the difference in height of diaphragmatic domes, (6) to analyze effect of degree of inspiration on the cardiothoracic ratio and (7) to analyze if there is any gender difference in the degree of inspiration and cardiothoracic ratio.

The study is an Cross sectional observational pilot study carried out at Department of Radiodiagnosis of a Medical College from India comprising of study population of healthy Indian young adults seeking admission for undergraduate (MBBS) course who have undergone screening Chest Radiographs and Ultrasonography abdomen as a part of mandatory medical examination prior to admission in July–August 2016.

Inclusion and selection criteria

All consecutive medical graduate aspirants undergoing screening medical examinations were included.

Exclusion criteria

Any structural abnormality or technically suboptimal radiograph likely to confound any of the measurements and findings.

Ethical issues

Institutional Ethics Committee Approval was obtained for the study.

Radiographic technique

Postero-anterior (PA) view of the chest was obtained in the erect position in all cases in full inspiration using 800 mA Direct Digital radiograph machine (Siemens). Chest radiographs were done before ultrasonography and all subjects were in fasting state and had about 500–1000 ml of drinking water as a part of preparation for ultrasonography of the abdomen 10–15 min prior to chest radiography. All chest radiographs were archived in the departmental image server as a part of daily routine. Soft copies of the chest radiographs of the study population were transferred to another workstation through LAN. Chest radiographs were loaded in DICOM viewing software (RadiAnt) for detailed analysis. All measurements were done with the electronic calliper available with the DICOM viewing software.

Study technique

Soft copies of all chest radiographs were loaded in the DICOM viewing software (RadiAnt) and the following were noted: (a) degree of inspiration by counting anterior ends of the ribs above the right dome of diaphragm in the mid clavicular line, (b) type of cardiac disposition: type I: 1/3rd of heart to the right of midline, 2/3rd to the left (classic position of the heart), type II: more than 1/3rd to the right of midline, type III: more than 2/3rd of the heart to the right of midline and type IV: more than 2/

3rd to the left of midline, (c) maximum cardiac transverse dimension (as shown in Fig. 1), (d) maximum internal thoracic dimension (as shown in Fig. 1), (e) cardiothoracic ratio (Fig. 1, calculated in Excel sheet from c and d), (f) presence or absence of gastric fundic bubble, (g) morphology of the gastric fundic bubble. Gastric fundic bubble demonstrating only gas was labelled as type I and those having air fluid level was labelled as type II (as shown in Fig. 2), (h) fundo-cupolic distance was measured as the shortest vertical distance from the visible inner lining of the stomach bubble to the upper diaphragmatic outline, (i) presence or absence of gas filled splenic flexure,

Fig. 1 – Method of measuring maximum transverse cardiac diameter, maximum internal thoracic diameter and cardiothoracic ratio (CTR). A vertical line is drawn in the mid sagittal plane as shown in the figure. A perpendicular line is drawn at the level of maximum transverse dimension of the right heart border and distance is measured (A). Another perpendicular line is drawn to the maximum transverse dimension of the left heart border and distance is measured (B). One horizontal line is drawn connecting the internal aspect of thoracic ribs at the level of maximum transverse dimension (C). CTR is obtained by the formula: C divided by A + B.

(k) types of diaphragmatic outline depending on the appearance of junction of medial most diaphragm with that of the right cardiac margin. Type I: the diaphragm has an acute angle with the right cardiac border, Type II: the diaphragm joins the right cardiac border almost at a right angle, Type III: the diaphragm joins the right cardiac border at an obtuse angle (as shown in Fig. 3), (l) difference in the level of domes of diaphragm (Fig. 4) were noted in each case. Diaphragmatic domes were easily identified in type I diaphragm for measurement purposes. In type II diaphragms, the plateau joining the right cardiac border was taken as diaphragmatic dome. In type III diaphragm: the highest point of the diaphragm adjacent to the right cardiac border was taken as the landmark. Gastric fundic bubble was considered displaced medially if more than 2/3rd of the maximum width of visualized fundic bubble was seen lying within the medial half of the hemi-diaphragmatic contour. Splenic flexure was considered prominent when most part of the splenic flexure in the given field of view was easily seen as gas filled structure and/or the gastric bubble was seen to be displaced by the splenic flexure. All the images were analyzed by a senior radiologist along with a radiology resident having 22 years and 2 years of experience respectively in chest radiology. Any discrepancy in the observation was resolved by mutual agreement between the two observers.

Statistical analysis

All data obtained were tabulated in excel sheet for further analysis. The data was analyzed descriptively. The quantitative variables were represented with mean $\pm$ SD and the qualitative variables using percentage. For all the variables, various percentile values were calculated. To determine whether the variables are significantly different among male and female students unpaired t test was used. To detect any statistically significant difference between the Cardiac Diameter, Thoracic diameter and CT ratio in the full inspiration category, one-way ANOVA was used. The post hoc analysis was done using Bonferroni test. *p* values of less than 0.05 were considered statistically significant. All the analysis was done using statistical software SPSS 23.0.

Fig. 2 – Types of gastric fundic bubble based on morphology and gas pattern. Type I: Gastric fundic bubble demonstrating only gas, Type II: Gastric fundic bubble demonstrating air fluid level.

Fig. 3 – Types of diaphragm depending on visible angle between right dome of diaphragm and right cardiac border: (a) Type I: the diaphragm has an acute angle with the right cardiac border. The dome of diaphragm is clearly visible; (b) Type II: the diaphragm joins the right cardiac border almost at a right angle; (c) Type III: the diaphragm joins the right cardiac border at an obtuse angle. Please note that the diaphragmatic slope is steep and there is no discernible dome in this type of diaphragm.

Fig. 4 – Method of measuring difference in diaphragmatic dome level. A horizontal line is drawn tangential to the highest dome of right (AB) as well as left (CD) hemidiaphragms. Distance (E) between these two lines (AB and CD) represents the difference in diaphragmatic dome level.

Results

A total of 560 chest radiographs available with the Dept of Radiodiagnosis were studied using the DICOM viewing software. Two radiographs were excluded from the final analysis because of scoliosis. A total of 558 chest radiographs were finally analyzed. The mean and median age of the subjects was 18.50 (SD = 1.00) and 18 respectively with range from 17 to 22 years. There were 497 (89.1%) male and 61 (10.9%) female subjects.

Degree of inspiration

The degree of inspiration in both sexes as adjudged by the level of anterior end of ribs above the dome of right hemidiaphragm in the mid-clavicular line was 5th, 6th, 7th and

8th ribs in 29 (5.1%), 259 (46.4%), 264 (47.3%) and 6 (1%) respectively. There was no significant difference in the level of full inspiration between males and females ($p = 0.22$).

Cardiac disposition

Most of the subjects had type I cardiac disposition (510, 91.4%) followed by type II (31, 5.5%), type IV (16, 2.9%) and type III (1, 0.17%) respectively.

Maximum transverse cardiac diameter

The mean maximum transverse cardiac diameter for all subjects was 1153.22 ± 120.01 mm (95% confidence interval 1143.04–1162.9 mm) with males having higher measurements (1164.62 ± 117.22 mm) as compared to females (1060.36 ± 101.28 mm). This difference was statistically significant ($p = 0.000$). On full inspiration, only 5% of the subjects had a cardiac diameter below 960 mm and another 5% had above 1353 mm respectively.

Internal thoracic diameter

The mean internal thoracic diameter for all subjects was 2935.24 ± 224.86 mm (95% confidence interval 2916.58–2953.9 mm) with males having higher measurements (2973.49 ± 201.44 mm) as compared to females (2623.57 ± 151.83 mm). This difference was statistically significant ($p = 0.000$). On full inspiration, only 5% of the subjects had an internal thoracic diameter below 2535 mm and another 5% had above 3278 mm respectively.

Cardiothoracic ratio

The mean cardiothoracic ratio (CTR) for all subjects was 0.39 ± 0.03 with females having slightly higher CTR (0.40 ± 0.03) as compared to males (0.39 ± 0.03). This difference was, however, statistically significant ($p = 0.009$). 5% of the subjects had a CTR below 0.34 and 5% above 0.45.

Table 1 – Mean maximum cardiac diameter, internal thoracic diameter and CT ratio in relation to degree of inspiration.

Descriptive			
	Level of inspiration (anterior end of corresponding ribs)	Mean	Std. deviation
Cardiac diameter	5th rib	1248.17 mm	104.13
	6th rib	1169.25 mm	115.48
	7th rib	1126.45 mm	118.27
	Total	1152.95 mm	120.05
Thoracic diameter	5th rib	3037.76 mm	266.09
	6th rib	2952.76 mm	223.98
	7th rib	2906.47 mm	216.97
	Total	2935.11 mm	225.07
CT ratio	5th rib	0.41	0.03
	6th rib	0.40	0.03
	7th rib	0.39	0.03
	Total	0.39	0.03

Relationship of cardiac diameter, thoracic diameter and cardiothoracic ratio with degree of inspiration

To detect whether there was any significant difference in the cardiac diameter, thoracic diameter and CT ratio with degree of inspiration (5th, 6th and 7th rib) we conducted one way ANOVA. The post hoc multiple comparison was done using Bonferroni test. The ANOVA analysis revealed that there was significant difference in the cardiac diameter ($p = 0.000$), thoracic diameter ($p = 0.003$) and CT ratio (0.000) amongst 5th, 6th and 7th rib. The pairwise post hoc multiple comparisons with p values for significant variables namely cardiac diameter, thoracic diameter and CT Ratio are given in Tables 1 and 2 and Figs. 5–7.

Gastric fundic bubble

Gastric fundic bubble was visualized in 508/558 (91%) subjects. Type I and type II gastric fundic bubbles were observed in 255 (45.6%) and 253 (45.3%) subjects. Gastric fundic bubble was displaced medially by prominent splenic flexure in 109 (19.5%) subjects.

Fundo-cupolic distance

The mean fundo-cupolic distance (FCD) for all subjects was 8.75 ± 8.00 mm with female subjects having lower mean FCD

Table 2 – Post hoc multiple comparisons using Bonferroni test for relationship between degree of inspiration and cardiac diameter, thoracic diameter, CT ratio.

Variable	Full inspiration		
	(5th, 6th rib)	(5th, 7th rib)	(6th, 7th rib)
Cardiac diameter	0.002*	0.000*	0.000*
Thoracic diameter	0.157 (NS)	0.008*	0.055 (NS)
CT ratio	0.022*	0.000*	0.009*

The values in the cells represent p values.

NS = not significant.

* Significant at 5% level of significance.

(5.72 ± 5.03 mm) as compared to males (9.17 ± 7.03 mm). This difference was again statistically significant ($p = 0.000$). A total of 173 (31%) of the total study group had FCD < 5 mm. A total of 145 (25.98%) subjects had FCD greater than 10 mm. Prominent splenic flexure displacing gastric fundic bubble medially was found in 47 (32.41%) such radiographs. 42 (7.5%) subjects had FCD > 20 mm. In 32 (76%) such cases, it was found that the increased FCD could be attributed to the interposition of free lateral edge of the left lobe of the liver.

Splenic flexure

Gas filled splenic flexure was visualized in 452 (81%) radiographs. Prominent splenic flexure was demonstrated in 162 (29%) radiographs out of which 109 radiographs demonstrated medial displacement of gastric fundic bubble as mentioned earlier.

Diaphragm types

Type I, II and III configuration of diaphragm was noted in 135 (24%), 352 (63%) and 71 (13%) radiographs respectively.

Fig. 5 – Relationship of maximum transverse cardiac diameter (in mm, Y axis) and degree of inspiration at various rib levels (X axis).

Fig. 6 – Relationship of maximum internal thoracic diameter (in mm, Y axis) and degree of inspiration at various rib levels (X axis).

Fig. 7 – Relationship of cardiothoracic ratio (CT ratio) (Y axis) and degree of inspiration at various rib levels (X axis).

Relative level of dome of diaphragm

Right dome of diaphragm was found to be at a higher level than the left in 527 (94.4%) radiographs. Both the domes were at the same level in 28 (5%) radiographs. Left dome of diaphragm was at a higher level than the right dome in only 3 (0.5%) radiographs. The mean value for difference in the level of two domes of diaphragm for all radiographs was 15.28 ± 5.38 mm with female subjects demonstrating a slightly lower value (13.06 ± 4.72 mm) as compared to males (15.53 ± 5.40 mm). This difference, however, was statistically significant ($p = 0.001$).

Summary of findings including various percentiles w.r.t. maximum transverse cardiac diameter, maximum internal thoracic diameter, CT ratio, fundo-cupolic distance, difference in diaphragmatic levels are shown in Table 3.

Discussion

Chest radiographs have always played an important role in the evaluation of disease processes affecting the

pleuro-pulmonary, mediastinal and cardiovascular structures since ages. Chest radiographs have stood the test of time as the initial imaging modality of choice in a multitude of diverse conditions despite tremendous advancements in the field of imaging including cross sectional imaging. Development of Computed Radiography (CR) and Digital Radiography (DR) technology has further ensured that chest radiographs will stay with us for a long time to come. The relative ease of obtaining a chest radiograph, wider availability and minimum radiation burden to the patients is some of the obvious advantages. CR/DR technology ensures better quality images and DICOM viewing software and workstation enables evaluation and measurement of various structures better than ever before. A basic understanding and interpretation of chest radiographs is an inescapable need for every physician involved in patient care, being one of the most commonly performed radiological investigations. Understanding normal chest radiographic features and normal variations is essential before one goes on to interpret abnormal findings. However, there is paucity of literature describing normal chest radiographic features particularly in the last two decades. This may be partly due to the growing and overwhelming use of cross sectional imaging, including ultrasonography, CT scan or MRI. Another possible reason could be the fact that it is unethical to subject an apparently asymptomatic and normal individual for chest radiographs for the sake of studying normal findings and variation. The present study was designed to evaluate certain important findings and variations of normal chest radiographs, knowledge of which is so often taken for granted by many of us. This is particularly so for the Indian subcontinent as most of the data in the textbook are from studies that originated in the Western population and therefore may or may not be truly applicable in our setting. We had the opportunity to retrospectively analyze digital chest radiographs of 560 apparently asymptomatic and healthy Indian young adults (17–21 years) who had undergone chest radiography as a part of mandatory medical examination before admission for the undergraduate medical course.

Degree of inspiration

Majority of the radiographs revealed either 6th ($n = 259$, 46.4%) or 7th rib ($n = 264$, 47.3%) as the marker for level of full inspiration. This is commensurate with the existing knowledge on this subject. An interesting fact that has come out of our study is that there was no significant difference in the level of full inspiration between males and females ($p = 0.216$).

Cardiac disposition

It is commonly accepted that the cardiac shadow on PA chest radiographs extends of 1/3rd to the right and 2/3rd to the left of midline which we have termed as type I disposition. Our study also reiterates the same finding that majority (>90%) of subjects will have a typical Type I disposition of the heart. However, it is important to note that 9–10% of individuals can have other types of cardiac disposition as a normal finding. To the best of our knowledge, such a variation in the type of cardiac disposition has not been described in the literature.

Table 3 – Details of maximum cardiac diameter, internal thoracic diameter, CT ratio, fundo-cupolic distance and diaphragm level difference with various percentile values as per gender.

Descriptive statistics		Cardiac diameter (mm)		Thoracic diameter (mm)		CT ratio		Fundo-cupolic distance (mm)		Diaphragm level difference (mm)	
Mean (SD)	Female	1060.36 (101.28)		2635.57 (151.84)		0.40 (0.04)		5.72 (5.03)		13.06 (4.72)	
	Male	1164.62 (117.22)		2973.49 (201.44)		0.39 (0.03)		9.17 (7.03)		15.54 (5.40)	
	Total	1153.22 (120.01)		2935.24 (224.86)		0.39 (0.03)		8.75 (6.90)		15.29 (5.38)	
Median	Female	1053.00		2629.00		0.40		4.50		13.35	
	Male	1162.00		2980.00		0.39		7.00		15.20	
	Total	1153.00		2952.00		0.39		6.70		15.00	
Minimum–maximum	Female	822.0–1296.00		2180.0–2963.0		0.32–0.48		1–30		4.5–25.00	
	Male	852.0–1494.00		2117.0–3549.0		0.30–0.50		1–40.0		2.0–32.00	
	Total	822.00–1494.00		2117.00–3549.00		0.30–0.50		1.00–40.0		2.00–32.00	
Percentile values	Cardiac diameter (mm)		Thoracic diameter (mm)		CT ratio		Fundo-cupolic distance (mm)		Diaphragm level difference (mm)		
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	
5	923.40	973.80	2398.00	2652.00	0.36	0.34	1.32	2.34	5.22	7.50	
10	929.40	1009.60	2449.60	2721.60	0.37	0.35	1.72	3.00	6.61	9.00	
25	986.50	1083.00	2515.00	2833.00	0.38	0.37	2.78	4.30	9.37	11.70	
50	1053.00	1162.00	2629.00	2979.00	0.40	0.39	4.50	7.00	13.35	15.20	
75	1135.50	1248.00	2729.50	3109.00	0.43	0.41	7.30	11.97	15.77	19.00	
90	1211.00	1319.40	2816.80	3216.00	0.46	0.43	10.64	20.00	19.75	22.50	
95	1247.50	1357.20	2936.90	3293.00	0.47	0.45	17.63	22.40	20.62	25.00	

Cardiothoracic ratio

The mean cardiothoracic ratio (CTR) found in this study was 0.39 ± 0.03 . This figure is rather on the lower side when compared to most of the studies on this subject^{3–6} and existing knowledge on this subject. One possible reason could be lower age group of the study population as it is well documented that CTR shows a positive correlation with age with the exception of infants and small children. Most of the studies conducted on CTR are in adult population and therefore knowledge of normal CTR in young adolescents is practically unknown. The present study provided a unique opportunity to look into the facts and figures about CTR in the age group of 17–21 years. Knowledge of normal transverse cardiac dimension and CTR as has been brought out in the present study can have major implication for diagnosing cardiomegaly at a much lower CTR rather than the traditional figure of 50%, which is actually applicable for adult population. It may be worthwhile to assess normal cardiac dimensions and CTR in different age groups in a larger study but for the limitation of subjecting a healthy population to the potential risk of radiation, however negligible it may be.

Another important and interesting fact brought out in this study is the occurrence of relatively higher CTR in females (0.40 ± 0.03) as compared to the males (0.39 ± 0.032) despite lower mean cardiac transverse diameter (1060.36 ± 101.28) in the female subgroup. This can be attributed to the significantly lower ($p = 0.000$) internal thoracic diameter in females (2623.57 ± 151.83 mm) as compared to males (2973.49 ± 201.44 mm). This finding may have implication while interpreting cardiomegaly in males and females, a concept that has not been brought out so far in the existing literature to the best of our knowledge.

The study brought out yet another interesting fact that CTR decreases significantly as the degree of inspiration increases progressively from the level of 5th to 6th to 7th ribs. This happens primarily because of significant reduction in the cardiac transverse diameter on progressive inspiration.

Gastric fundic bubble

Visualization of gastric fundic bubble is an integral part of the check list of reading normal chest radiographs. Gastric fundic bubble was visualized in 91% of radiographs, a fact which reiterates the benefit of present day digital radiography over conventional radiography in the past.⁷ While gastric bubble may be absent in many pathological conditions, it is important to remember that certain percentage of normal individuals (e.g. 9% in this study) may also demonstrate absence of gas filled fundic bubble as contrary to normal expectation, despite best possible quality of chest radiograph. Gastric bubble displacement by various pathological processes is well known. However, the present study revealed the fact that gastric fundic bubble may be displaced medially by a prominent and gas filled splenic flexure in as many as 20% of normal subjects. This concept may be relevant in understanding normal variations of the gastric fundic bubble. The study also demonstrated almost equal number of two distinct morphological types of stomach bubble (Type I & II), a concept which may be important in understanding morphology of stomach bubble.

Gastric fundo-cupolic distance (FCD) is another important parameter studied while interpreting a normal chest radiograph which helps to suspect presence of sub-diaphragmatic pathology. We could not find any reference for normal FCD. However, it is mentioned in authoritative Text books of

Radiology⁸ that the combined thickness of diaphragm and stomach wall is 5–8 mm. Therefore, FCD more than 8–10 mm may raise an alarm to look for a variety of sub-diaphragmatic pathologies. Importantly, the present study revealed that nearly 26% of the population had FCD >10 mm. None of them had any detectable abnormality in abdominal ultrasonography, which immediately followed chest radiography, to account for relatively high FCD. Almost, 1/3rd of such cases had medially displaced gastric fundic bubble due to prominent splenic flexure. Majority (76%) of cases of relatively high FCD (>20 mm) could be attributed to interposition of the free lateral edge of the left lobe of liver. All these findings indicate that there is a need to be cautious before interpreting increased FCD as pathological. It is also interesting to note that 31% cases had FCD <5 mm against an expected normal dimension of 5–8 mm.

Splenic flexure

The study demonstrated presence of gas filled splenic flexure in as high as 81% cases, a fact which is not well documented in the literature. The possibility of prominent splenic flexure medially displacing gastric fundic bubble as a normal variation is likely to help in routine chest radiographic interpretation.

Relative level of dome of diaphragm

As expected, right dome of the diaphragm was found to be higher in majority of radiographs (94.4%). Both domes of diaphragm were at the same level in 5% cases. This finding is commensurate with the existing knowledge. However, the left dome of diaphragm was found to be higher than the right dome in only 0.5% cases as opposed to 3% documented by Felson.⁹ It is commonly mentioned that a difference of 3 cm between the two domes of diaphragm is significant.⁸ However, there are some practical issues in measuring the difference in the level of domes of diaphragm. We have observed three different morphological appearance of right dome of diaphragm on a chest PA view, which we labelled as Type I–III depending on the angle at which the right dome is seen abutting the right cardiac border. We found the classic pattern of Type I (where there is a distinct dome with downward slopes on both sides) only in 24% cases. Measurement of difference between domes of diaphragm is expected to be accurate in this group of cases. As many as 63% of diaphragms demonstrated an up-slope on the lateral aspect followed by a plateau joining the right cardiac border almost at right angle (type II). This type of diaphragm does not have a proper dome in the true sense. The Type III pattern of the dome of diaphragm seen in only 13% of subjects demonstrates a continuous upslope medially and joins the right cardiac border at an obtuse angle. It would be extremely difficult to identify the apex of the dome of diaphragm in this type of diaphragm morphology. While interpreting elevated dome of diaphragm on a PA chest radiograph it may be helpful to make a mention of the type of diaphragm to enable correct interpretation.

Our study establishes the mean value of difference in diaphragmatic dome level in both sexes. Interestingly, the study reveals that females have a lower value for mean difference in the diaphragmatic levels. The study results also

depict various percentile values for differences in diaphragmatic dome levels.

Strength of the study

We have studied various normal features and variations on chest radiographs in an apparently healthy Indian adolescent population, which, to the best of our knowledge, is not described in the literature. The study highlights various deviations from the existing knowledge which may be clinically relevant. There is paucity of literature on the topics covered by the study. Various figures and percentiles found and documented in this study can serve as normal reference values at least for the age group studied particularly in the Indian context.

Limitations

Our study suffers from two important limitations.

The study is only about a particular age group and therefore cannot be generalized for the entire age ranges.

Female population is only 10.9% of the entire study population, although gender differences in many parameters were statistically significant. The investigators had no control in the selection of cases since they were part of a routine screening medical examination.

Conclusion

The existing knowledge of normal variations in the appearance of various structures on normal chest radiographs has been based on studies predominantly conducted in the adult western population. This study reveals normal range of findings in young Indian adolescents which are at variance with the commonly accepted data. There are also statistically significant gender differences in these findings. It may be worthwhile to keep these differences in mind while interpreting chest radiographs in the Indian young adult population.

Conflicts of interest

The authors have none to declare.

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