

A Study of Heart and Thoracic Size and Cardiothoracic Ratio on Chest Radiography in Digital-Radiography System

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Abstract

Due to changes to Digital-Radiography system (DR system), its distance of film and object is longer than that in Film-Screen system (F/S system). However, current chest radiography exam has been the same as in F/S system. The objective of this study was to present real Heart Size (HS), Thoracic Size (TS), and Cardiothoracic Ratio (CTR) on chest Posterior-Anterior (chest PA) and chest Anterior-Posterior (chest AP) in the DR system and to determine the statistical correlation between Focal-Film Distance (FFD) and HS, TS, or CTR during chest AP. Our results revealed that HS, TS, and CTR in chest PA and chest AP of the DR system were larger than their real sizes. HS was especially magnified 8% and 22% in chest PA and chest AP, respectively. HS, TS, and CTR all had significant ($p < 0.05$) negative correlation with FFD. In addition, HS and TS as well as HS and CTR had significant ($p < 0.05$) positive correlation.

Keywords: Chest AP, Chest PA, Cardiothoracic Ratio, Heart Size, Thoracic Size

1. Introduction

Chest X-ray is a common non-invasive tool to evaluate health with relatively low cost¹. It can be used to evaluate lung diseases (such as lung cancer, tuberculosis, pneumonia and pneumothorax), heart diseases (such as cardiac hypertrophy and ventricle hypertrophy), and other diseases occurring in thorax (such as pleurisy, pleural effusion). Because of that, chest X-ray accounts for 30~60% of all radiography in general X-ray².

Generally, chest radiography acquired chest Posterior-Anterior (chest PA) projection with Film-Focus Distance (FFD) at 180~200 cm and chest Anterior-Posterior (chest

AP) projection with FFD at 100 cm [3~5]. Chest PA processes erect position mostly. If erect position is disabled, patients can take chest AP with a sitting or supine position. However, these exam methods were made for film-screen system (F/S system). Therefore, the Object-Film Distance (OFD) has been changed under the present Digital-Radiography system (DR system).

The purpose of this study was to present real Heart Size (HS), Thoracic Size (TS), and Cardiothoracic Ratio (CTR) on chest PA and chest AP in the DR system and to determine the statistical correlation between FFD and HS, TS, or CTR during chest AP.

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2. Materials and Methods

2.1 Materials

This study used Chest phantom (76-083, Victoreen), XGEO GC80 (Samsung Electronics, Korea) of X-ray equipment, and Discovery CT 750 HD (General Electronic Medical System, USA) of Computed Tomography equipment were used. Images were measured by Centricity Radiology RA 1000 (General Electronic, USA) PACS system.

2.2 Methods

Chest CT axial, chest PA, and chest AP were acquired using Chest phantom. Chest PA image was acquired by positioning phantom to PA position with FFD at 180 cm. Chest AP image was acquired by positioning phantom to AP position with FFD from 100 cm to 270 cm.

2.2.1 Measurements of HS, TS, CTR

HS, TS, CTR measurements were performed by three researchers at different time and places so that they would not affect each other's measurements or share their results. CTR measuring methods for Chest PA and AP images were shown in Figure 1(a, b)^{3,4,8}. For CT images, the largest heart of CT axis image used in Kim Yoo Sung etc. study referred to the original (Figure 1(c)) was used to measure heart transverse diameter and thorax diameter.

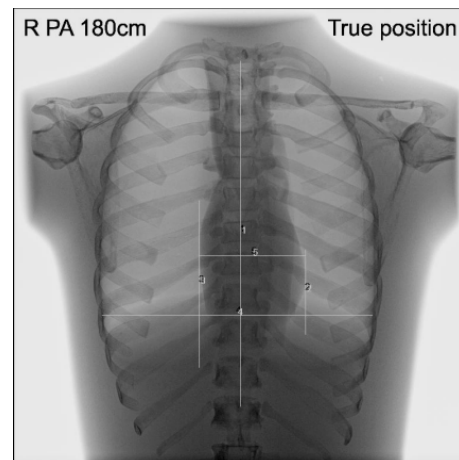
2.2.2 Statistical Analysis

Kolmogorov-Smirnov test was used to determine whether the result of chest phantom image fall into normal distribution. One-way ANOVA was used to compare values between groups. Turkey B was used for post-hoc comparison. Pearson correlation analysis was used to test the correlation of HS, TS, or CTR with FFD. SPSS (version 12.0, SPSS Inc. Chicago, IL, USA) statistical program was used to perform statistical analysis. Statistical significance was considered when p value was less than 0.05.

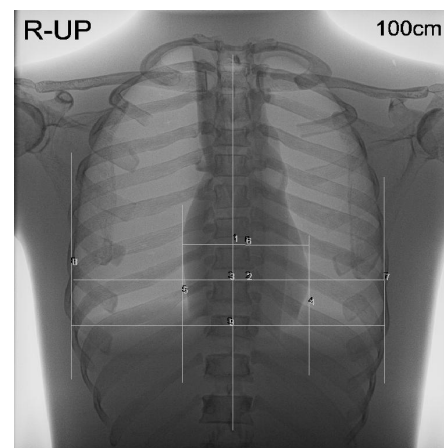
3. Result

3.1 HS, TS and CTR Magnification Degree in chest PA and chest AP

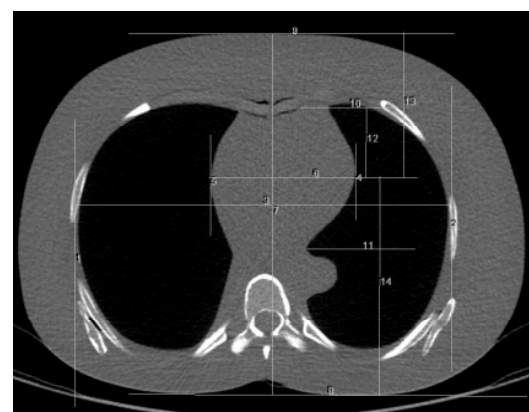
The comparison and analysis results of HS, TS, CTR values in chest CT, chest PA, and chest AP images are summarized in Table 1. HS, TS, and CTR values in



(a)



(b)



(c)

Figure 1. Measurement on Chest PA, Chest AP, Chest CT images. (a) is Chest PA image at FFD 180 cm, (b) is Chest AP image at FFD 100 cm, (c) is Chest CT axial image.

Table 1. Result of One-way ANOVA about HS, TS, CTR on chest phantom test

Variable	n	HS(mm)	TS(mm)	CTR
		(avg±std)	(avg±std)	(avg±std)
Chest PA (FFD 180cm)	3	99.73±.30 ^a	256.53±3.59 ^a	58.88±.43 ^a
Chest AP (FFD 100cm)		113.33±1.76 ^b	282.96±2.54 ^b	40.04±.32 ^b
Chest CT		92.33±.40 ^c	258.35±2.48 ^c	39.37±.36 ^a

chest CT, PA, and AP were 92.33 mm, 258.35 mm, and 39.37; 99.73 mm, 256.53 mm, and 38.8; 113.33 mm, 282.96 mm, and 40.04, respectively. The average difference in chest CT, PA, AP shows statistical significance ($p < 0.05$).

1. p-values are calculated by one-way ANOVA
2. * $p < 0.05$
3. a,b,c: Same letters indicates statically indifferent by Turkey B multiple comparison
4. HS: heart size; TS: thoracic size; CTR: cardiothoracic ratio (on images)

3.2 Correlation between FFD and HS, TS or CTR

HS, TS, and CTR all had significant negative correlation with FFD (Table 2).

In addition, HS and TS as well as HS and CTR had significant positive correlation.

1. p-values are calculated by Pearson's correlation analysis
2. * $p < 0.05$, ** $p < 0.01$
3. FFD: film-focus distance, HS: heart size, TS: thoracic size, CRT: cardiothoracic ratio (on images)

Table 2. Result of correlation analysis between FFD and HS, TS, CTR on chest phantom

Variable	n	FFD	HS	TS	CTR
FFD	18	1			
HS		-.946**	1		
TS		-.960**	.990**	1	
CTR		-.548*	.697**	.587*	1

4. Discussion

Chest PA and AP exams are all regular radiologic exams for all thorax diseases. They have the advantage to check all shapes and condition changes by showing image of chest. However, it is important to get high quality images because it is very difficult to diagnosis if complicated anatomical structures show single plane images comparing to CT. Although the atrium and ventricle of heart cannot be seen exactly, chest X-ray is useful to diagnose and check heart shape, detect abnormal findings of pulmonary and track changes. In addition, it can be sued for differential diagnosis of pulmonary edema reasons. Hypertrophy of heart is very important. In 1919, Danzer announced that hypertrophy of heart could be suspected if CTR was more than 0.5. If CTR was over 0.52, it indicated obvious abnormality⁷. Cardiothoracic change has been reported in aging population, pregnant and confinement period, regular dialysis patients, patent ductus arteriosus after gyeolchalsul, and asthma patients. However, for chest AP, CTR can be affected when chest diameter is smaller than the original because heart is positioned in front of chest⁸. Therefore, magnified heart and FFD is closer than in chest PA. In addition, patient cannot hold the maximum inspiration⁶. These factors could cause heart shape to have small changes. For chest PA, more horizontal changes will occur. For chest AP, more traversal changes will be induced. In addition, abdomen pressure in chest AP is higher than that in chest PA. The diaphragm is lifted up above heart. Due to the growth of heart transverse diameter, heart has been shown larger than normal. For chest PA, the low extremity blood stream has shown lower. But for chest AP, the blood flow is increased because the processing of hydrostatic pressure is the same as in heart and low extremity^{9,10}. Due to these reason, in real clinical set-

ting, standard judgment to evaluate heart size with chest AP of critical patients is equivocal. Ovenfords has reported that we need to exam chest AP before operation for kidney dialysis patients' clinical management. It is important to measure CTR to dialysis room front and back to resist opinion¹¹. Also, CTR can be changed by breath status, diaphragm changing, positioning, exposure distance, image sharpness. In addition, CTR can be improved by age growth, pregnant and postpartum period, heart failure after postpartum, and regular blood dialysis patients^{12,13}.

4.1 The Consideration of HS, TS, CTR Magnification Ratio for Chest PA and AP

CT axial images have sharpness and resolution better than X-ray images. This study was performed to compare chest CT images for HS, TS, CTR magnification ratio. When chest PA was compared to CT axial images, HS was increased by 8%, but TS and CTR were decreased to 0.7% and 1.2%. Such errors could be due to sharpness of CT in chest PA. However, for chest AP, HS, TS, and CTR were increased by 22%, 9.5%, and 1.7%, respectively. For chest AP, HS, TS, and CTR were increased by 13%, 10%, and 2.3% compared to chest PA. These three groups on average have statically difference ($p<.05$), which was in consistent with the results reported by Park Seok Hee⁴. Simple x-ray cardiothoracic ratio average was 0.45. CT cardiothoracic ratio was 0.46, which had different results from that reported by Kim Yoo Sung⁷. Post-hoc comparison revealed similar results.

4.2 The Consideration of FFD and HS, TS, CTR Correlation for Chest AP

Correlation analysis revealed that FFD and HS, TS, or CTR had significant negative correlation. Therefore, if a patient can sit down correctly during chest AP, radiology technicians could protect heart and cardiothoracic ratio using the longest FFD as much as possible. Also, HS affected CTR more than TS. This could be due to the fact that heart traverse diameter was positioned in front of thorax traverse diameter. Through this study, it could be known how much distortion and change to HS, TS, and CTR could be brought by FFD for Chest AP.

5. Conclusion

Our results revealed that HS, TS, and CTR in chest PA and chest AP of the DR system were larger than their real

sizes. Heart size was especially magnified 8% and 22% in chest PA and chest AP, respectively. HS, TS, and CTR all had significant ($p<0.05$) negative correlation with FFD. In addition, HS and TS as well as HS and CTR had significant ($p<0.05$) positive correlation.

6. References

1. Han KY, Ho CJ. et al. Association of aortic calcification on plain chest radiography with obstructive coronary Artery Disease. Korea Society of Radiological Science. 2009; 31(1):33–8.
2. Ja LI, Han KY. et al. Evaluation of image according to exposure conditions using contrast-detail phantom for chest digital radiography. Korea Society of Radiological Science. 2009; 32(1):25–32.
3. The Korean Society of Medical Imaging Technology. Textbook of Radiographic Positioning and Clinical Diagnosis. 3rd ed. CHUNG-KU Publishing co; 2008. 2:466.
4. Park S-H, Lee Y-I. et al. Comparative study on cardiac measurement between standard PA and supine AP views of the chest. J Korean Radiol Soc. 1980; 16(2):438–42.
5. Park EG, Lee KY. et al. The usefulness of magnification of the heart shadow in chest radiography. Korean J Digit Imaging Med. 2010; 12(2):119–25.
6. Chon S-B, Oh W-S. et al. Calculation of the cardiothoracic ratio from portable anteriorposterior chest radiography. J Korean Med Sci. 2011; 26:1446–53.
7. Kim Y-S, Park H-J. et al. A CT criteria of cardiomegaly. J Korean Radiol Soc. 2007; 57:235–8.
8. Kim HG. The findings on cardiothoracic ratio in simple chestradiograph. Korea Society of Radiological Science. 2004; 27(4):43–8.
9. Habbe JE. The influence of posture on size and configuration of the heart as seen teroentgen ographically. Am J Roentgenol. 1956; 76:706–20.
10. Schorr S, Dreyfuss F. et al. The recumbent esophagram: an X-ray method for early detection of left atrial enlargement. Radiology. 1971; 57:208–13.
11. Ovenfords CO, Hedgcock MW. Intensive care unit radiology: problems of interpretation. Radiol Clin Norh Am. 1978; 16:407–36.
12. Galal O, von Sinner W. et al. Clinical result and radiographic appearance of the Rashkind double umbrella device in patients with occlusion of ductus arteriosus. Pediatr Radiol. 1997; 27:936–41.
13. Theodore E, Keats P. Atlas of roentgenographic measurement. 6th ed. Verginia: Mosby Elsevier Health Science; 1990.