Original Article

Cardiothoracic Ratio (CTR) Cut-Off Value on Chest CT in Non-Cardiomegaly Patients

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Objective: To determine the cardiothoracic ratio (CTR) cut-off value on chest computed tomography (CT) in non-cardiomegaly patients.

Materials and Methods: The authors reviewed 97 patients who underwent both posteroanterior view chest radiograph and chest CT between September 2010 and September 2013. The interval time between the two image studies was two weeks. Patient demographic and clinical data, including age, gender, underlying pulmonary and heart disease, and CTRs from posteroanterior chest radiograph and chest CT were reviewed and recorded.

Results: Of the 97 non-cardiomegaly patients, 50 (51.5%) patients were male and 47 (48.5%) were female. Patient age ranged from 23 to 78 years (mean 55.9±13.4). Eighteen patients (19%) had CTR from chest radiograph between 0.350 and 0.400, with mean CTR from chest CT at level of biggest heart of 0.42±0.02. Forty-two patients (43%) had CTR from chest radiograph between 0.401-0.450, with mean CTR from chest CT at level of biggest heart of 0.47±0.03. The remaining 37 patients (38%) had CTR from chest radiograph between 0.451 and 0.500, with mean CTR from chest CT at level of biggest heart of 0.51±0.03.

Conclusion: The CTR cut-off value on chest CT for indicating cardiomegaly was found to be 0.53

Keywords: Cardiothoracic ratio, Cardiomegaly, CT cardiothoracic ratio

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The diagnosis of patients with cardiomegaly is most easily made via cardiothoracic ratio (CTR) from a posteroanterior chest radiograph. CTR is calculated as the ratio of maximal transverse diameter of the cardiac silhouette (heart diameter) to the distance between the internal margins of the ribs (transverse thoracic diameter), as determined by posteroanterior chest radiograph with the patient in the upright position. If the CTR is greater than 0.50, cardiomegaly is assumed in the adult patient[1,2].

The CTR is increased when the patient is evaluated in the supine position due to magnification of cardiac shadow and inadequate inspiration effect, even though the patient does not have cardiomegaly. The authors, therefore, postulated that the CTR from the chest CT performed in the supine position should be greater than the CTR from the chest radiograph in the same position.

The objective of the present study was to determine the CTR cut-off value on chest CT in non-cardiomegaly patients.

Materials and Methods

Patients

The authors retrospectively reviewed adult non-cardiomegaly patients aged 18 years or older that underwent both posteroanterior chest radiograph and chest CT that had an interval time between the two image studies of two weeks. After review and approval of the present study protocol by the Siriraj Institutional Review Board (SIRB) (COA no. Si 755/2013), 97 patients that underwent both posteroanterior view chest radiograph and chest computed tomography (CT) between September 2010 and September 2013 were enrolled. The authors excluded patients having heart and lung

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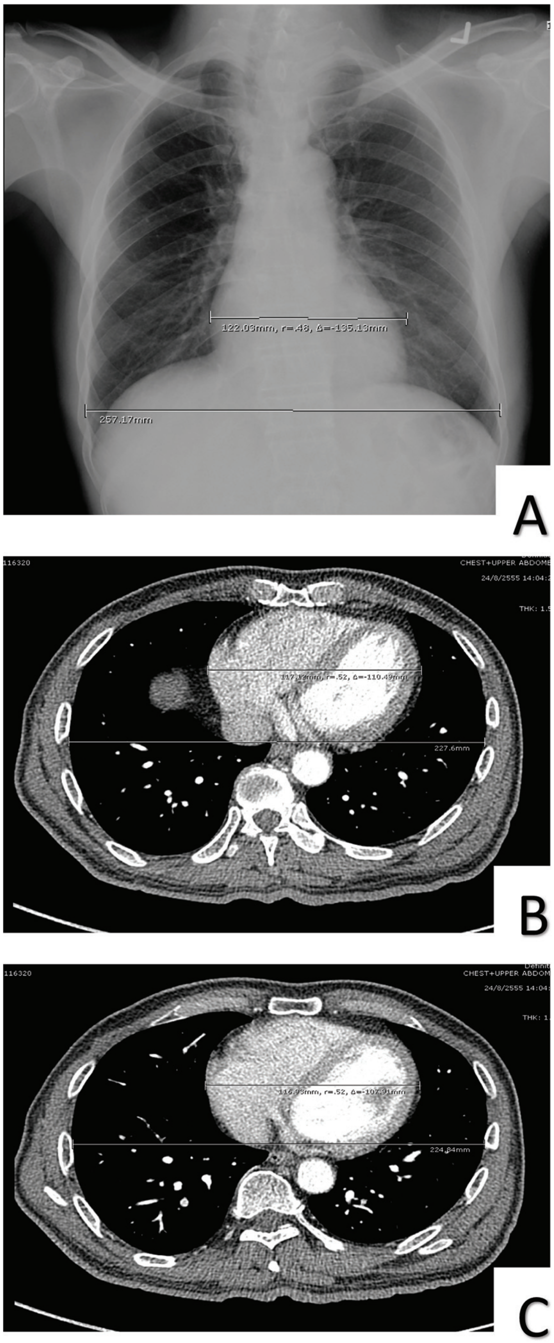

Figure 1. A 64-year-old male with rectal cancer had CTR from chest radiograph of 0.48 (A). CTR from chest CT at right diaphragmatic apex (B) and at level of biggest heart (C) were equal (CTR=0.52).

disease, as determined by CTR measurement. Patient demographic and clinical data, including age, gender, underlying pulmonary and heart disease, and CTRs from posteroanterior chest radiograph and chest CT were reviewed and recorded. Measurement of CTR was performed. For the chest radiograph, the CTR was defined as the widest transverse cardiac diameter from right to left border of cardiac shadow divided by the widest transverse thoracic diameter from inner to inner chest wall in posteroanterior view chest radiograph[3-5]. For chest CT, the authors measured CTR at two levels, the level of upper most right hemidiaphragm[6] and the level of the biggest heart, both of which defined the widest transverse cardiac diameter from outer to outer pericardium and divided by the widest transverse thoracic diameter from inner to inner chest wall[7], on axial image with adjusted mediastinal window (Figure 1).

Image analysis

Twenty of the 97 patients were randomly selected for evaluation of the inter-observer and intra-observer reliability of CTR measurement. Two experienced board-certified thoracic radiologists separately interpreted the CTR from both chest radiograph and chest CT on each patient (inter-observer reliability), and one third-year radiology resident interpreted CTR from both chest radiograph and chest CT two times for each patient (intra-observer reliability). If reliability was high, imaging from the remaining 77 patients could be interpreted by one radiologist. All studies were interpreted on a picture archiving and communication system (PACS) workstation.

Statistical analysis

Inter-observer and intra-observer reliability in evaluation of CTR were assessed using intraclass correlation coefficient (ICC). Scatter plot and simple linear regression analysis were used to determine the linear regression equation for CTR from chest radiograph versus CTR from chest CT scan. Statistical analysis was performed using PASW Statistics, version 18.0 (SPSS Inc., Chicago, IL, USA). A p-value of less than 0.05 was statistically significant.

Results

Of the 97 non-cardiomegaly patients, 50 (51.5%) were male and 47 (48.5%) were female. Patients' age ranged from 23 to 78 years (55.9±13.4).

Inter-observer and intra-observer reliability

Inter-observer and intra-observer CTR reliability from chest radiograph and chest CT were assessed using 20 patients. Results showed very high inter-observer and intra-observer reliability, with ICC ranging from 0.94 to 0.99 (Table 1, Figure 2).

Table 1. Inter- and intra-observer reliability in 20 patients

	CTR from chest radiograph ICC (95% CI)	CTR from chest CT at diaphragmatic apex ICC (95% CI)	CTR from chest CT at level of biggest heart ICC (95% CI)
Inter-observer			
Two thoracic radiologists	0.98 (0.96 to 0.99)	0.94 (0.85 to 0.98)	0.98 (0.94 to 0.99)
One thoracic radiologist vs. one radiology resident	0.94 (0.79 to 0.98)	0.96 (0.90 to 0.98)	0.97 (0.92 to 0.99)
Intra-observer			
Two measurements by one radiology resident	0.98 (0.96 to 0.99)	0.99 (0.97 to 1.00)	0.99 (0.96 to 0.99)

ICC=intraclass correlation coefficient; CI=confidence interval; CTR=cardiothoracic ratio; CT=computed tomography

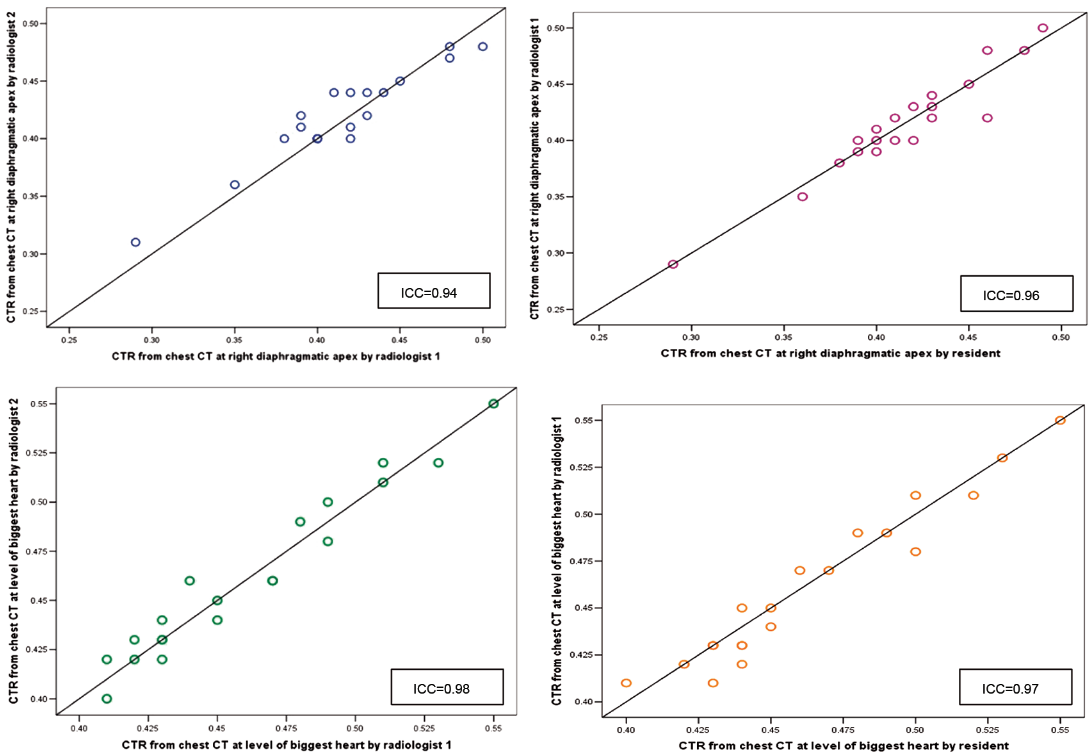

Figure 2. Inter-observer and intra-observer reliability of CTR measurement by two thoracic radiologists and one radiology resident in 20 non-cardiomegaly patients.

Therefore, chest radiograph and chest CT in the remaining 77 patients were interpreted once by one radiologist (38 and 39 patients were reviewed by radiologist 1 and radiologist 2, respectively).

CTR value and comparison of CTR from chest radiograph and chest CT

CTR from chest radiograph ranged from 0.36 to 0.50 (mean 0.44). CTR from chest CT at right diaphragmatic apex varied from 0.29 to 0.58 (mean 0.45) and at the level of biggest heart from 0.36 to 0.58 (mean 0.48). Difference in CTR between chest radiograph and chest CT at right diaphragmatic apex ranged from –0.110 to 0.140 (mean –0.009). Difference in CTR between chest radiograph and chest CT at the level of biggest heart varied from –0.120 to 0.030 (mean –0.036) (Table 2).

Chest CT CTR value in each group of chest radiograph CTR

From the 97 patients, 18 patients (19%) had CTR from chest radiograph between 0.350 to 0.400, 42 (43%) between 0.401 to 0.450, and 37 (38%) between 0.451 to 0.500. In the first chest radiograph CTR

Table 2. CTR values and differences in CTR values between chest radiograph and chest CT at right diaphragmatic apex and level of biggest heart in 97 patients

CTR	Mean±SD	Min, max
Chest radiograph	0.44±0.04	0.36, 0.50
Chest CT at right diaphragmatic apex	0.45±0.06	0.29, 0.58
Chest CT at level of biggest heart	0.48±0.04	0.36, 0.58
Difference between chest radiograph and chest CT at right diaphragmatic apex	–0.009±0.049	–0.11, 0.14
Difference between chest radiograph and chest CT at level of biggest heart	–0.036±0.031	–0.12, 0.03

SD=standard deviation; CTR=cardiothoracic ratio; CT=computed tomography

Table 3. CTR value from chest CT at right diaphragmatic apex and level of biggest heart in each chest radiograph CTR group

CTR from chest radiograph	n (%)	CTR from chest CT at right diaphragmatic apex Mean±SD	CTR from chest CT at level of biggest heart Mean±SD
0.350 to 0.400	18 (19)	0.39±0.04	0.42±0.02
0.401 to 0.450	42 (43)	0.47±0.05	0.47±0.03
0.451 to 0.500	37 (38)	0.48±0.05	0.51±0.03

SD=standard deviation; CTR=cardiothoracic ratio; CT=computed tomography

Table 4. Agreement in CTR from chest radiograph and chest CT at right diaphragmatic apex and level of biggest heart (n=97)

	ICC (95% CI)
Chest radiograph vs. chest CT at right diaphragmatic apex	0.52 (0.36 to 0.65)
Chest radiograph vs. chest CT at level of biggest heart	0.51 (–0.04 to 0.77)

ICC=intraclass correlation coefficient; CI=confidence interval; CT=computed tomography

Table 5. Simple linear regression equation of chest radiograph CTR relative to chest CT CTR

Measurement location	p-value of slope	R^2	Predicted Y when X=0.5
CTR from chest CT at right diaphragmatic apex = 0.049 + 0.909*X	<0.001	0.334	0.5035
CTR from chest CT at level of biggest heart = 0.99 + 0.833*X	<0.001	0.507	0.5255

X=CTR from chest radiograph; CTR=cardiothoracic ratio; CT=computed tomography

range (0.350 to 0.400), CTR from chest CT at right diaphragmatic apex and at level of biggest heart had means of 0.39 and 0.42, respectively. For the second chest radiograph CTR range (0.401 to 0.450), CTR from chest CT at right diaphragmatic apex and at level of biggest heart had equal means of 0.47. For the last group with chest radiograph CTR range (0.451 to 0.500), CTR from chest CT at right diaphragmatic apex and at level of biggest heart had means of 0.48 and 0.51, respectively (Table 3).

CTR agreement between chest radiograph and chest CT

CTR agreement between chest radiograph and chest CT (n=97) at right diaphragmatic apex and level of biggest heart was fair with ICCs of 0.52 and 0.51, respectively (Table 4). At the level of biggest heart, CTR from CT was greater than that of chest radiograph in most cases.

Simple linear regression analysis of chest CT CTR relative to chest radiograph CTR

Due to poor agreement between CTR from chest radiograph and chest CT, a simple linear regression analysis was performed to identify the CTR value from chest CT when CTR value from chest radiograph is equal to 0.5. The simple linear regression equation of chest radiograph CTR relative to chest CT CTR is

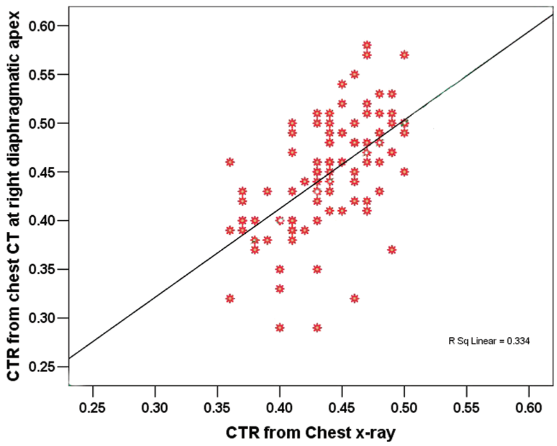

Figure 3. Line of equality (dotted line) and linear regression line (solid line) of CTR from chest CT at diaphragmatic apex on chest radiograph.

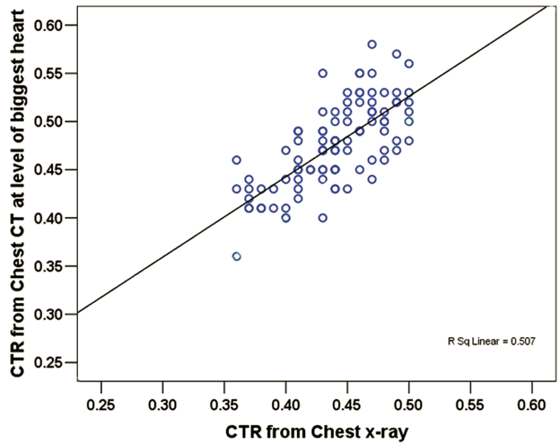

Figure 4. Line of equality (dotted line) and linear regression line (solid line) of CTR from chest CT at level of biggest heart on chest radiograph.

shown in Table 5. The R^2 of 0.334 indicated that 33.4% of variation in chest CT CTR at right diaphragmatic apex can be explained by chest radiograph CTR. Therefore, the R^2 of 0.507 (between chest CT CTR and chest radiograph CTR at level of biggest heart), which was higher and better, showed that chest CT CTR at level of biggest heart was more accurate than chest CT CTR at right diaphragmatic apex. Linear regression lines are displayed in Figure 3 and 4.

Discussion

Based on the present study review of the literature, only two studies mention CTR on chest CT[2,8]. In both instances, it was reported that the cut-off CTR value on chest CT for indication of cardiomegaly was not more than 0.5. However, the authors often see an increase in cardiac silhouette on portable chest radiograph when the patient was radiologically evaluated in the supine position. This led to the authors' objective of determining whether the cut-off point for cardiomegaly on chest CT scan would be greater than 0.5.

In the present retrospective study, 97 patients received posteroanterior chest radiograph in the upright position, for which CTR was not more than 0.5, a CTR that represented non-cardiomegaly. All 97 patients also received chest CT, with the interval between the two radiographic investigations that was not exceeding two weeks.

In the present study, non-cardiomegaly patients CTR value from posteroanterior chest radiograph in upright position may have been less or greater than the CTR from chest CT at diaphragmatic apex in supine position (min –0.11, max 0.14). As such, mean difference in CTR between chest radiograph and chest CT was very close to zero (mean difference –0.009). Scatter plot of CTR from chest radiograph and chest CT at diaphragmatic apex showed poor agreement (Figure 3).

The CTR value from chest CT at level of biggest heart was greater than that from chest radiograph, resulting in poor agreement. As shown in the scatter plots in Figure 3 and 4, the R-squared value revealed that variation in chest CT CTR at the upper most right diaphragmatic apex was greater than that of chest CT CTR at level of biggest heart. It was, therefore, logical to investigate CTR from chest CT at the level of biggest heart.

In the supine position, transverse cardiac diameter on chest CT tends to increase as a result of diminished degree of inspiration and rib expansion, as compared to the same patient's performance in the upright position on chest radiograph[9]. It should be noted that CTR from chest CT at the level of biggest heart was more than that from chest radiograph, but some CTRs from chest CT at the right diaphragmatic apex were less than the values from the chest radiograph. This may be explained by the fact that greatest cardiac diameter does not locate at the level of the right diaphragmatic apex.

According to the linear regression analysis, chest radiograph CTR of 0.5 corresponds to chest CT CTR of 0.53 at the level of biggest heart and chest CT CTR of 0.50 at right diaphragmatic apex, with CTR values exceeding these cut-offs representing cardiomegaly. In the authors' professional opinion, CTR from chest

CT should be measured at the level of biggest heart, as described above.

Possible limitations of the present study include the low ICC (95% CI) of CTR from chest radiograph, as compared with chest CT CTR at right diaphragmatic apex and chest CT CTR at the level of biggest heart in 97 patients; however, 20 of 97 patients showed high ICC (95% CI). Another limitation may be that our population did not include chest radiograph CTRs of less than 0.35.

Conclusion

Given a result of the present study, the authors recommend using CTR of 0.53 as the cut point number to indicate cardiomegaly for chest CT scan in adult.

What is already know on this topic?

Usually, cardiomegaly is defined as the CTR exceeds 0.5 on chest radiograph

What this study adds?

This study tried to find the cut-off value to define cardiomegaly on chest CT. The cut-off number from the present data is 0.53.

Conflicts of interest

The authors hereby declare no personal or professional conflicts of interest regarding any aspect of the present paper.

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