Cardiac Dimensions Derived From Helical Ct: Correlation With Plain Film Radiography

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Citation

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Abstract

PURPOSE Although it has been a widely followed principle that a cardiothoracic ratio (CTR) of <0.5 constitutes a "normal" heart s ize on a posteroanterior (PA) chest radiograph (CXR), little has been done to define heart size on helical CT (HCT). We will atte mpt to correlate the radiographic measurement of CTR with various easily reproduced methods of deriving CTR by HCT.
METHODS PA CXR and HCT performed within a week of one another we re retrospectively reviewed on 93 consecutive individuals (90 mal e, mean age 64 yrs.). CTR, the ratio of the greatest transverse cardiac diameter to greatest transverse thoracic diameter, was de rived from both the CXR and HCT for each patient. The dimensions obtained from the CXR and HCT were compared.
RESULTS CTR obtained by measuring the transverse cardiac dimensi on differed by an average of only 0.038/patient between CXR and H CT, which was not statistically significant (p>.44), while a CTR index derived from averaging the long and short axis cardiac diam eter on HCT differed from radiographic transverse CTR by a simila r 0.044/patient.
CONCLUSION There is no significant difference in CTR, the tradi tional standard of cardiac enlargement, derived from either CXR o r HCT. Therefore, CTR may be a useful, rapid means of correlatin g an individual's heart size between the two modalities.

INTRODUCTION

The cardiothoracic ratio (CTR) is the fraction derived by measuring the distance from the midline to the most lateral aspect of the left and right heart borders (left apical and right atrial silhouettes, respectively) and dividing that sum by the maximum horizontal measurement of the thorax, from left pleural surface to right pleural surface (generally taken at the level of the diaphragmatic apices) on a posteroanterior chest radiograph (CXR). The determination of CTR can be performed and reproduced rapidly and with considerable precision, even without aid of a ruler or other measuring device. Therefore, since first described by Danzer in 1919, it has been a widely followed practice in chest radiography is to consider a CTR of greater than 0.5 as representing cardiomegaly (CM)([1],[2],[3]). Unfortunately, little direct correlation of radiographic CTR has been made to CTR as derived from computed tomography (CT), in particular, helical CT (HCT). Therefore, it is our experience that radiologists tend to overlook the consideration of cardiac size, unless grossly abnormal, when interpreting CT scans, regardless of clinical indication. Furthermore, if we can standardize a simple means of determining heart size by both radiography and cross-sectional imaging utilizing CTR, an association between cardiomegaly and measurements of cardiac function (such as ejection fraction (EF) or cardiac output) may be more accurately established in the near future. Therefore, we will attempt to validate the relationship of CTR, as derived from a PA CXR, to CTR derived utilizing various readily derived axial cardiac measurements on HCT of the chest.

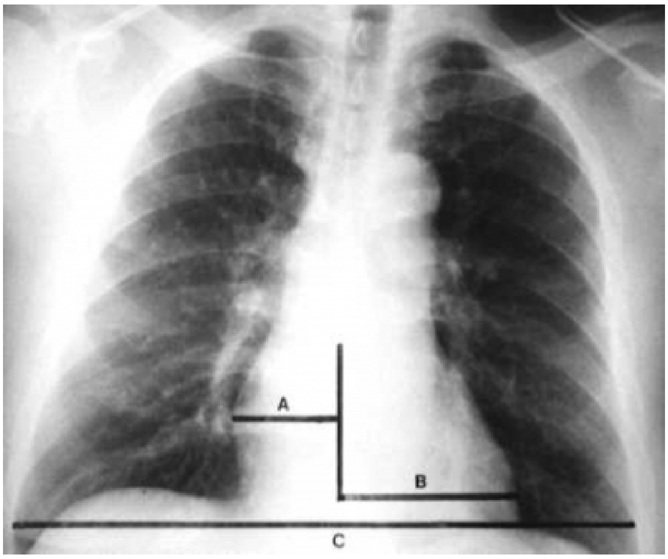
MATERIALS AND METHODS

We reviewed the radiologic and medical records of 521 consecutive individuals who underwent thoracic HCT at our Veteran's Administration Medical Center over a 6-month interval for a variety of indications. Of these, 93 (90 male, 3 female, avg. age 64 yrs.) received a Posteroanterior CXR within one week of the HCT. This cohort comprised our study population.

Determination of radiographic CTR (RCTR) was performed as follow: One of three radiologists measured the distance, in cm, using a standard clear plastic ruler, from the midline of the spine horizontally to the most lateral aspect of the cardiac apex. This procedure was repeated in a similar fashion from the midline of the spine to the most lateral aspect of the right atrium. These two measurements were added and divided by the largest horizontal width of the chest, from left to right pleural surface, derived at the level of the left hemidiaphragmatic silhouette (fig. 1). An RCTR >0.5 was considered to represent cardiomegaly.

Figure 1

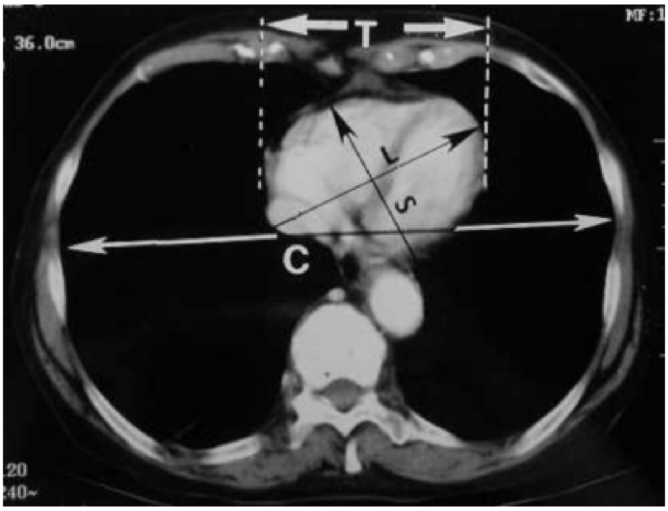
Fig. 1. Standard (Danzer) method of measuring CTR using a posteroanterior CXR. CTR=A+B/C



Several methods were employed to estimate cardiac size in the axial plane from thoracic HCT originally performed for evaluation of non-cardiac chest disease. All HCT were performed on a commercially available unit (Picker PQ2000S, Picker International, Highland Heights, OH) employing a pitch of 1.5 with 5mm collimation reconstructed at 8mm intervals. Intravenous contrast was utilized in the majority of studies (80%). The first analysis was an attempt to reproduce the RCTR using cross-sectional technology. A slice level was selected that represented the maximum size of the heart in the axial plane. A vertical line was then drawn, perpendicular to the CT table, extending through the thorax tangent to the most lateral aspect of the cardiac apex. A second vertical was drawn, in a similar fashion, tangent to the most lateral aspect of the right cardiac border (right atrial wall) at the same slice level as the cardiac apex. The horizontal distance between the two lines was measured with a standard calipers and the numerical distance was determined from the scale that appears on the side of each CT image. This distance was divided by the horizontal distance of the thorax at the level of the dome of the left hemidiaphragm. Again, calipers were utilized. This constituted the computed tomographic CTR (CTCTR) (fig. 2). Calipers were also used to measure the greatest axial length, parallel to the intraventricular septum, (i.e. "long axis") and maximum axial distance perpendicular to the septum (i.e. "short axis") of the heart at the same slice level as was used to derive the transverse cardiac diameter. These measurements were again divided by the maximum horizontal thoracic dimension. A "cardiac index" was then derived by averaging the long and short axis measurements and dividing this number by the horizontal thoracic diameter as well.

Figure 2

Fig. 2. Various methods of deriving CTR on HCT. CTR using the maximum transverse cardiac diameter, T (superior white arrows), is an attempt to replicate radiographic CTR (Transverse CTR=T/C). L, the long cardiac axis (black arrow pointing to left ventricular apex) and S, the short axis (black arrow pointing medially) are used to derive a HCT CTR index (CTR index=0.5(L+S)/2). The transverse thoracic diameter, C (inferior white horizontal arrows), would normally be taken several centimeters caudal to this image, at the level of the dome of the left hemidiaphragm, to simulate the radiographic measurement. It has been included at this level to complete this figure.



Each of the three radiologists (JAM, AS, SC) evaluated 31 radiographs and 31 HCT performed on different individuals (for a total of 186 separate observations) so that no observer assessed both the CXR and HCT on the same patient. This was done to prevent idiosyncratic differences between the methodology of each of the three physicians from significantly affecting the data. The radiologists were blinded as to the measurements obtained by their colleagues.

The paired t test and standard chi-square tests were performed to establish the significance of the difference between the various above measurements in each individual.

RESULTS

The mean maximum horizontal cardiac diameter, maximum horizontal thoracic dimension and CTR for the group, as determined by PA CXR were 15.71 cm, 30.44 cm and 0.505, respectively. The mean maximum transverse cardiac diameter, maximum thoracic dimension and CTR measured from the HCT were 14.74 cm, 27.70 cm and 0.52, respectively. The mean CTR's derived from measuring the cardiac long axis, short axis and cardiac index from the HCT were 0.52, 0.42 and 0.48, respectively.

The transverse diameter of the heart derived from CXR differed to a small but statistically significant degree, on a per patient basis, from that obtained from the HCT (mean 0.95 cm/patient, range 0-4.5 cm, p<0.001). In all but 8 cases (91%), the HCT derived measurements were smaller than or equal to those of the corresponding CXR. Similarly, on a per patient basis, the measurement of the transverse diameter of the thoracic cavity also differed by a small but significant amount between the two modalities (mean 2.92 cm/patient, range 0-10 cm, p<0.001). In all but 2 (97%) cases, the HCT derived dimensions were smaller than or equal to those from the corresponding CXR. Therefore, CTR obtained by measuring the maximum transverse cardiac and thoracic dimensions differed by an average of only 0.038/patient between CXR and HCT, which was not statistically significant (p>.442). Similarly, CTR derived by averaging the long and short axis cardiac diameter on HCT (i.e. utilizing the cardiac index) differed, on a per patient basis, by a similar 0.044/patient (p>.31).

DISCUSSION

When interpreting a PA CXR, it is standard practice to denote a CTR >0.5 as representing cardiomegaly. Although many other estimates of heart size and chamber volumes have been devised, the CTR remains the easiest to employ, requiring neither a ruler nor a lateral film ([4,5,6,7,8]). Interestingly, our experience reveals that no such universal standard of cardiac size exists for CT, particularly HCT. Rarely is the term, "cardiomegaly," even employed when interpreting a CT scan, and if it is, it is generally used to connote a massively dilated heart that occupies most of the thorax in the axial plane. This lack of uniformity is interesting to note in light of the ease at which precise measurements of size can be obtained on CT, utilizing the scale that is incorporated on the edge of each image. Therefore, our results may aid in standardizing a simple, reproducible, rapidly employed means of describing cardiac dimensions on CT and offer a useful comparison with CXR.

The posteroanterior CXR is taken at a standard focal distance of 72 inches. Therefore, there is little additional divergence of the x-ray beam as it emerges from an anterior thoracic structure, such as the heart, to impart an image on the film situated against the anterior chest wall ([9]). Accordingly, it is not surprising that the measurements of the horizontal transverse dimensions of the heart and thorax were similar between HCT and CXR, with the CT derived measurements being consistently <10% smaller than those of the CXR. Some of this disparity between the two modalities is likely due to the mild degree of magnification still present as the x-ray photons diverge and scatter between the myocardium and film screen system. Additional error is also imparted as the single radiographic image may be obtained in either systole or diastole, which, along with other physiologic factors such as total intravascular volume, may induce up to a 2 cm change in cardiac dimension (2). In the majority of CXR, however, the cardiac silhouette changes very little in serial studies (3). Perhaps the greatest source of discrepancy between the radiographic and axial tomographic derivation of transverse cardiac diameter can be attributed to the fact that the transverse cardiac diameter on CXR is computed by adding the distance from the midline to the most lateral aspects of the left and right heart borders. On CT, however, in an effort to maximize simplicity, we utilized a single axial section for all measurements, which would be unlikely to contain both the greatest leftward and rightward distances from the midline simultaneously. The thoracic diameter is, of course, subject to slight changes in degree of inspiration between radiographic exams. HCT, on the other had, depicts multiple images, only the largest of which were used for measurement in our study. The supine positioning of an individual on the CT gantry, however, would tend to diminish the degree of inspiration and rib expansion as compared the same person's performance while standing for a CXR. Interestingly, the relatively consistent, positive difference between CXR and HCT derived measurements of both cardiac and thoracic diameter caused these differences in radiographic and tomographic dimensions to be factored out and allowed the resulting CTR's to remain almost identical (i.e. no significant difference) between the two modalities.

Whereas the CTR derived using the two dimensional transverse cardiac dimensions on HCT simulates the projection of the standard PA CXR, we felt that obtaining additional measurements, incorporating the long and short axis, would provide a more accurate, three dimensional assessment of heart size. In theory, it would reduce the error induced on a frontal transverse image due to differences in degree of cardiac rotation within the thorax or of unusually elongated or foreshortened ventricular shapes (i.e., for a heart of the same volume, one with very foreshortened but wide ventricles or one that is rotated in a counterclockwise direction would appear small in the transverse plane, while one with elongated ventricles or clockwise rotation would appear large). In fact, in past studies correlating radiographic indexes of cardiac size with true morphologic or angiographically obtained values, better agreement was noted when the lateral chest radiograph was utilized in addition the frontal measurements to derive an estimated cardiac silhouette volume (5,7). Interestingly, in our population, the average long axis and transverse cardiac measurements were the same (avg. 14.7 cm) and not substantially greater than the short axis dimension (avg. 11.6 cm). Therefore, the CTR derived by averaging the long and short axis measurements, meant to more closely approximate cardiac volume from a single HCT slice, did not differ significantly from the two-dimensional radiographic CTR (0.044/patient).

The key feature in correlating a radiographic and HCT-derived determination of cardiac dimension, regardless of the relationship to cardiac function, is in establishing an easily derived, reproducible means of quantifying heart size between the two modalities. Many means of obtaining very good estimates of cardiac and ventricular mass and function using CT have been published. Unfortunately, most must be performed prospectively with specific protocols or cardiac gating and may require substantial time for analysis ($_{10}$). Therefore, such procedures are impractical in estimating or comparing HCT cardiac dimensions in everyday practice. The CTR can be determined in several seconds, manually, on any CT scan of the chest or abdomen (as all full abdominal CT scans include the lower thorax) regardless of collimation, pitch or use of intravenous contrast.

In conclusion we have established that a simple, reproducible determination of CTR can be derived from any HCT that correlates very closely with the standard measurement of CTR obtained from the CXR. Therefore, CTR can be used as a cross-modality reference of cardiac size. The correlation of CTR with cardiac function awaits further study.

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