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### Permalink

<https://escholarship.org/uc/item/0p26m0d6>

### Journal

Journal of Thoracic Imaging, 30(3)

### ISSN

0883-5993

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### Publication Date

2015-12-01

### DOI

10.1097/RTI.0000000000000132

Peer reviewed

# Left Atrial Transverse Diameter on Computed Tomography Angiography Can Accurately Diagnose Left Atrial Enlargement in Patients With Atrial Fibrillation

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**Purpose:** Left atrial (LA) enlargement is associated with increased risk for adverse cardiovascular events. We assessed the accuracy of LA transverse and antero-posterior (AP) diameters obtained from chest computed tomography (CT) angiography in patients with atrial fibrillation.

**Materials and Methods:** Nongated contrast-enhanced 64-slice multidetector CT angiography (slice thickness of 0.625 to 1.25 mm) was used to measure the volume and transverse and AP diameters of the LA in 222 subjects. The internal contours of the LA and LA appendage were outlined in 1 of every 5 axial images, and the LA area was multiplied by 5 times the slice thickness. Maximum transverse and AP diameters of the LA were measured, excluding the appendage. Receiver operating characteristic curves were fitted to assess the accuracy of the diameters. A Wald test was used to compare the area under the curves.

**Results:** The mean age of patients was  $60.0 \pm 10.6$  years, and 71% were male. Median LA volume was  $55.9 \pm 24.4$  mL/m<sup>2</sup>. LA enlargement was present in 83% of the patients. Transverse and AP LA diameters were accurate estimators of the LA enlargement. The transverse diameter demonstrated higher accuracy than the AP diameter, with area under the curves of 0.89 (0.84 to 0.94) and 0.81 (0.73 to 0.89), respectively ( $P < 0.05$ ). A transverse LA diameter of 7.3 cm had a sensitivity and specificity of 85% for detection of LA enlargement. At the same sensitivity level, an AP diameter of 4.3 cm had a specificity of 60.5%.

**Conclusions:** Transverse LA diameter can accurately detect LA enlargement in patients with atrial fibrillation. This parameter can be used for detection of patients with possible LA enlargement on chest CT angiography.

**Key Words:** left atrium, enlargement, chest, computed tomography, accuracy

(*J Thorac Imaging* 2015;30:214–217)

Left atrial (LA) enlargement is associated with increased risk for adverse cardiovascular events, including myocardial infarction, congestive heart failure, and stroke.<sup>1–8</sup>

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Grant support by American Roentgen Ray Society Scholar Award 2010–2012.

The authors declare no conflicts of interest.

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Previous studies have shown that LA volume can be reliably obtained from contrast-enhanced chest computed tomography (CT) scans.<sup>8–11</sup> The most precise method for volumetric quantification using CT is by manually tracing the area of LA on cross-sectional images.<sup>8</sup> However, this method is very time consuming and therefore is not routinely used in clinical practice. Moreover, when reading a chest CT study, it is often difficult and unreliable for the radiologist to determine the presence of LA enlargement on the basis of visual inspection alone, especially when there is only mild LA enlargement. In addition, there are no established threshold criteria for LA diameters that could aid in making this diagnosis. In clinical practice, most radiologists use the antero-posterior (AP) diameter of the LA as an indicator of LA enlargement. However, it is our hypothesis that as the LA grows, enlargement is greater along the transverse diameter axis than along the AP diameter axis due to constraints related to the spine and the heart.

The purpose of this study was to assess the accuracy of LA transverse diameter derived from nongated chest CT for detection of LA enlargement and compare with that of AP diameter. We also aimed to develop a simple and reliable formula for estimation of LA volume that could be applied easily in routine nongated chest CT evaluations.

The study was approved by the Institutional Review Boards of our institution.

## MATERIALS AND METHODS

### Study Population

We retrospectively included 222 consecutive subjects with refractory lone atrial fibrillation who were referred to our institution for chest CT angiography for pulmonary venous mapping before LA ablation. One hundred and forty-two patients (64%) were in sinus rhythm during the CT study. Table 1 shows the demographics, prevalence of comorbidities, and cardiac rhythm status in the study population.

### Imaging Studies

Nongated contrast-enhanced CT scans were performed by using either a 16 multidetector CT (GE LightSpeed<sup>16</sup>) or a 64 multidetector CT (GE LightSpeed VCT). The scan was performed during inspiratory breath-hold with a tube voltage of 120 kVp. On average, 100 to 120 mL of iodinated contrast agent (Iohexol, Omnipaque 350; GE Healthcare) followed by 40 mL saline solution was injected at a rate of 4 mL/s. Bolus tracking was performed with the region of interest within the LA to optimize LA

**TABLE 1.** Patient Demographics

Demographics	No. Patients (%) (Total = 222)
Male	158 (71)
Age (y)	60 ± 10.6
Body mass index (kg/m <sup>2</sup> )	29 ± 6.3
Comorbidities	
Diabetes mellitus	23 (10.6)
Hypertension	82 (37.1)
Coronary artery disease	23 (10.6)
Congestive heart failure	8 (3.8)
Rhythm	
Normal sinus rhythm	142 (64)
Atrial fibrillation	66 (30)
Atrial flutter	13 (5.9)

enhancement. Images were reconstructed with a slice thickness of 0.625 to 1.25 mm.

Imaging analysis was performed using a dedicated AGFA PACS workstation. LA volume was measured using the modified Simpson method. We manually outlined the internal contour of the LA appendage and LA, excluding pulmonary veins, in 1 of every 5 axial images of the chest and multiplied the sum of all LA areas by 5 times the slice thickness. Volumes were indexed to the body surface area. Maximum transverse and AP diameters of the LA were measured, excluding the appendage and the pulmonary veins, not indexed to the body surface area (Fig. 1). LA measurements were obtained by a single observer. The following simplified formula was proposed for estimation of the LA volume based on the AP and transverse diameters: (transverse diameter)<sup>2</sup> × AP diameter. This formula was used because the calculation of LA volume should be based on 3 dimensions, but the craniocaudal dimension is typically not known on an axial chest CT study without multiplanar reformation. We assumed that, given the geometry of the LA, the transverse diameter typically approximates the craniocaudal diameter.

The presence of LA enlargement was defined on the basis of the largest prior publication on the normal range of LA end-diastolic volumes measured by the cardiac CT volumetric method in a sample of patients without cardiac

disease.<sup>12</sup> The end-diastolic volume was used as a reference, as a prior study has shown that volumetric measurements performed on nongated CT images have a very high agreement with end-diastolic volumes acquired from an electrocardiography-gated image.<sup>13</sup> Patients with an LA volume indexed to the body surface area higher than the mean LA end-diastolic volume indexed plus 1 SD (41.8 mL/m<sup>2</sup>) were defined as patients with LA enlargement.

**Statistical Analysis**

STATA version 11 was used to analyze the data. Descriptive statistics including mean ± SD or median ± interquartile range were calculated. Receiver operating characteristic curves were fitted to assess the accuracy of the transverse and AP LA diameters for detection of LA enlargement. A Wald test was used to compare area under the curves. Threshold values with high sensitivity were determined for both transverse and AP LA diameters.

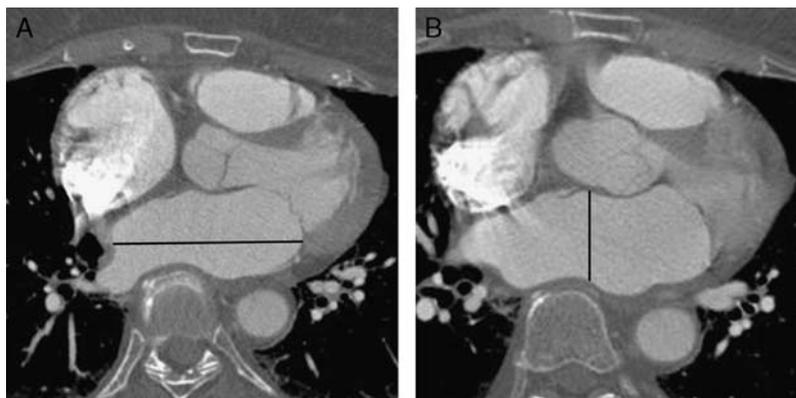
Bland-Altman analysis was performed to assess agreement between LA volumes obtained by the Simpson method and derived from the simplified formula using AP and transverse diameters.

Finally, logistic regression models were fitted to evaluate the association between both the AP and transverse diameter and the prevalence of LA enlargement, controlling for possible confounders including age, sex, and body mass index.

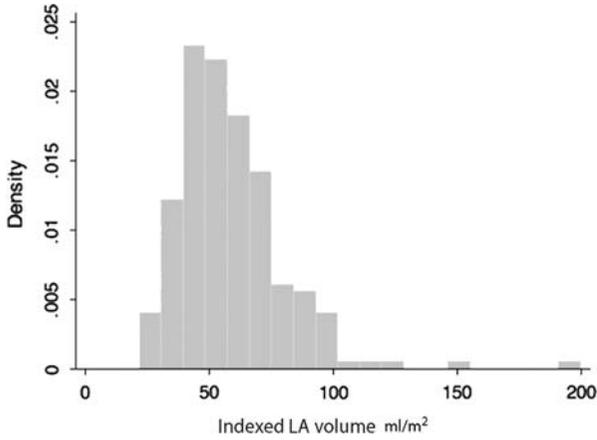
**RESULTS**

A total of 222 patients were enrolled. Patients had a mean (± SD) age of 60.0 ± 10.6 years, and 71% (158) were male. Table 1 shows the demographics, prevalence of comorbidities, and cardiac rhythm status in the study population. The rhythm was sinus during the CT study on 142 patients (64%). The median LA indexed volume was 55.9 ± 24.4 mL/m<sup>2</sup>. LA enlargement was present in 184 (83%) patients. Figure 2 presents the frequency of LA volume ranges.

The median (± interquartile range) AP and transverse diameters were 4.95 ± 1.05 and 7.80 ± 1.20 cm, respectively. Both transverse and AP LA diameters were accurate estimators of the presence of LA enlargement. However, the transverse diameter demonstrated higher accuracy than the AP diameter with an area under the curve of 0.89



**FIGURE 1.** A, Axial images of a contrast-enhanced CT in a patient with an enlarged LA based on volumetric CT quantification (1183 mL). Note the enlargement of the transverse diameter of the LA, which measured 8.5 cm. B, Axial images of a contrast-enhanced CT in a patient with an enlarged LA based on volumetric CT quantification (1183 mL). The AP LA diameter was not significantly enlarged, measuring 4 cm.



**FIGURE 2.** Histogram of LA volume indexed to the body surface area.

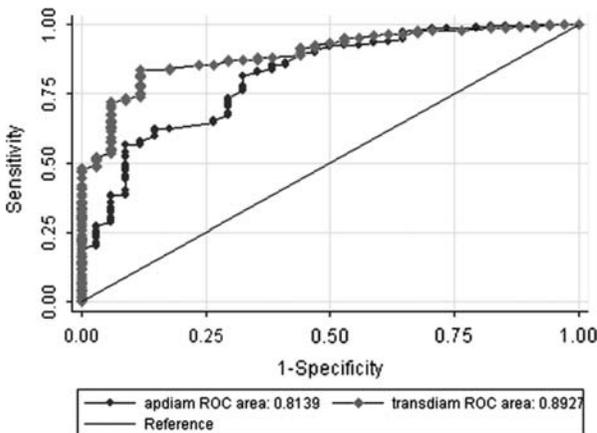
[confidence interval (CI): 0.84-0.94) and 0.81 (CI: 0.73-0.89), respectively ( $P < 0.05$ ) (Fig. 3). A transverse LA diameter of 7.3 cm had a sensitivity of 84%, a specificity of 84%, a positive predictive value of 96%, a negative predictive value of 52%, and an accuracy of 84% for detection of LA enlargement. At the same sensitivity level, an AP diameter of 4.3 cm had a specificity of 61%, a positive predictive value of 56%, a negative predictive value of 5, and an accuracy of 44% for the detection of LA enlargement.

There was reasonable agreement between the LA volume estimated on the basis of the transverse and AP diameters and the LA volume measured using the Simpson method, with a mean difference of 2.18 mL (CI: -0.637 to 5.003) and limits of agreement of -40.4 and 44.82 mL (Fig. 4).

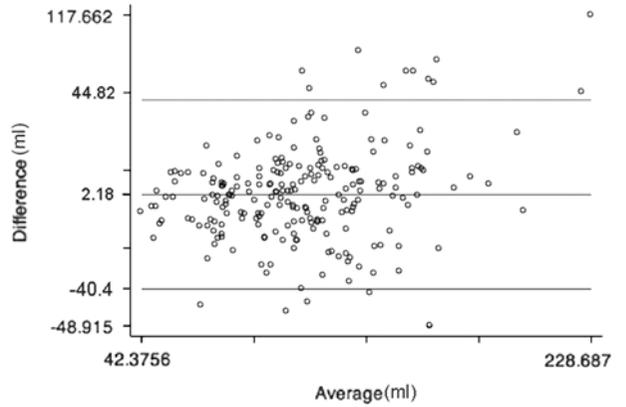
An independent statistically significant association ( $P < 0.001$ ) was observed between the AP and transverse diameter of LA with the presence of LA enlargement, with an odds ratio of 13.3 and 15.04, respectively.

**DISCUSSION**

Our results show that the transverse diameter of the LA is superior to the AP diameter in diagnosing LA



**FIGURE 3.** Receiver operating curve (ROC) analysis of transverse and AP LA diameter for detection of LA enlargement. Apdiam indicates AP diameter; transdiam, transverse diameter.



**FIGURE 4.** Bland-Altman analysis of agreement for LA volume measurement.

enlargement. With high sensitivity and specificity (84%), a transverse diameter  $>7.3$  cm can be used to detect LA enlargement on any nongated chest CT scan performed for numerous noncardiac clinical indications. A 1 cm increase in the transverse diameter was independently associated with an approximately 15-fold increase in the chance of having LA enlargement.

Our study proposes a simplified formula for estimation of LA volume, based on AP and transverse LA dimensions obtained from nongated chest CT studies. There is a good agreement between the LA volume estimated from the simplified formula and the volume measured on the CT using the Simpson method. Agreement was worse in patients with higher indexed LA volumes, likely because the simplified formula does not account for the volume of the LA appendage, which is typically very high when severe LA enlargement is present. The need to incorporate the transverse dimension of the LA on assessing LA volume on cross-sectional imaging has been previously addressed. Mahabadi and colleagues have shown a very good correlation between the axial area and the LA volume ( $r = 0.88$ ,  $P < 0.001$ ), whereas there was only a moderate positive correlation between the AP diameter and the volume ( $r = 0.67$ ,  $P < 0.001$ ). They have assessed the LA axial area from a single slice at the level of the left ventricular outflow tract and the height of the mitral valve leaflets.<sup>14</sup> In addition, Hof and colleagues validated a technique for estimation of LA volume based on the transverse, AP, and longitudinal dimensions of the LA. An excellent correlation between LA volumes determined by this new technique and the Simpson method was demonstrated.<sup>15</sup>

LA enlargement is an independent risk factor for adverse cardiovascular events. It is associated with coronary artery disease, increased risk for stroke, and myocardial infarction. In patients with atrial fibrillation, LA enlargement is associated with increased risk for AF recurrence after ablation. As there is no established threshold for diagnosing LA enlargement on nongated chest CT, the presence of this disease is typically not reported, and a high-risk patient may be undiagnosed. Therefore, the use of an LA transverse diameter  $>7.3$  cm as an indicator of the presence of LA enlargement with subsequent confirmation with echocardiography or cardiac-gated CT may have a significant impact on a patient's clinical management. When the proposed threshold is applied to a population with a disease

prevalence of 16%, which is the reported prevalence of atrial fibrillation in the middle-aged US population, the expected positive predictive value would be approximately 52%. Therefore, for every 2 patients referred for echocardiography for confirmation of the presence of LA enlargement, 1 patient would in fact have the disease. The clinical impact of detecting LA enlargement in patients undergoing chest CT for noncardiac indications remains to be addressed in prospective outcomes and cost-effective analysis studies.

A limitation of our study is that it involved patients with refractory atrial fibrillation and thus larger LA volumes than the general population. However, unlike the positive and negative predictive values, which are significantly influenced by the prevalence of the disease, sensitivity and specificity of a test are not influenced by the disease prevalence. The severe spectrum of disease seen in our population likely resulted in a slight overestimation of the sensitivity, the so-called spectrum bias.

In conclusion, transverse LA diameter can accurately detect LA enlargement in patients with atrial fibrillation. This parameter can be used for detection of patients with possible LA enlargement on routine chest CT angiography, prompting confirmatory evaluation with echocardiography.

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