The Correlation between Subcarinal Angle and Left Atrial Volume

Sir-Chen Lin, Jui-Heng Lee and Chih-Min Hsieh

Background: Widening of the tracheal bifurcation angle on chest radiograph is mentioned as a sign of left atrial (LA) enlargement. However, the clinical usefulness of this sign as a diagnostic tool remains controversial. The aims of our study were: 1) to determine the relationship between subcarinal angle and echo-measured LA volume, and 2) to assess the diagnostic value of measuring subcarinal angle for predicting LA enlargement.

Methods: A total of 376 subjects who underwent echocardiography between September 2004 and June 2007 were enrolled in our study. LA volumes data were obtained, and then indexed by body surface areas. LA enlargement was defined as LA volume index (LAVI) > 28 ml/m^2. Subcarinal angles of each subject were calculated using their chest posterior-anterior view, and data were analyzed by statistical methods.

Results: Application of Student's t-test disclosed subcarinal angles which were significantly greater in patients in the LA enlargement group than those outside the LA enlargement group ($p = 0.0035$). Furthermore, linear regression revealed a significant positive correlation between subcarinal angles and LAVI ($r = 0.41$, $p < 0.001$). However, ROC curve showed no optimal cut-off value of subcarinal angle which could predict LA enlargement.

Conclusion: Our study demonstrated that the subcarinal angle measured by chest radiograph significantly correlated with echo-measured LA volume. However, there was no practical upper limit of "normal" subcarinal angle which was efficacious for detecting LA enlargement.

Key Words: Left atrial volume • Subcarinal angle

INTRODUCTION

The left main bronchus normally rests upon the left auricle, just adjacent to the bifurcation of the trachea. In 1838, King first observed compression and distortion of the left main bronchus due to an enlarged left auricle.[1] In 1910, Stoerk measured the angles at which bronchi leave the trachea, and noticed that both the left and right angles of bronchus were greater in cases with mitral disease than in normal cases.[2] However, the above studies were carried out on autopsy material. After the discovery of the X-ray, in 1924, Gabert first visualized the widening of the tracheal bifurcation angle on a chest radiograph in a patient with an enlarged left atrium.[3] In 1928, case series of mitral stenosis reported by Steele pointed out the elevation of the left main bronchus due to an enlarged left auricle.[4] Increase of the angle of tracheal bifurcation has been frequently mentioned as a sign of enlarged left atrium.[5] In order to clarify the clinical usefulness of this sign, we conducted this study to investigate the relationship between subcarinal angle and echocardiographically measured left atrial (LA) volume. We also assessed its diagnostic value for predicting LA dilatation.

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Division of Cardiology, Department of Internal Medicine, Taipei City Hospital, Renai Branch, Taipei, Taiwan.
Address correspondence and reprint requests to: Dr. Jui-Heng Lee, Division of Cardiology, Department of Internal Medicine, Taipei City Hospital, Renai Branch, No. 10, Sec. 4, Ren Ai Road, Taipei, Taiwan. Tel: 886-2-2709-3600 ext. 3741; Fax: 886-2-2704-9399; E-mail: DAA71@tpech.gov.tw

METHODS

This retrospective study was approved by the Taipei

City Hospital Institutional Review Board. We reviewed data derived from patients who received echocardiography in Taipei City Hospital Renai Branch between September 2004 and June 2007. A total of 376 subjects ranging in ages from 15 to 96 years were enrolled. The subjects consisted of 171 males and 205 females, and were primarily hospital outpatients. Subjects with conditions that might distort bronchial anatomy were excluded, including deformity of thoracic spine column, mediastinal diseases, lung fibrosis, lung atelectasis, lung mass, pleural effusion and pericardial effusion.

LA volumes were measured with two-dimensional transthoracic echocardiography (Agilent SONOS 5500) at the end-systolic phase. Apical four- and two-chamber views were obtained in left lateral recumbent position. The transducer was angulated carefully to maximize cardiac chamber sizes, and the gains of zoomed areas were adjusted to achieve the clearest outline of the endocardium. Pulmonary veins and LA appendage were excluded from outlines. End-systole was determined in the frame just prior to mitral valve opening. We calculated LA volumes using the method of Goerke and Carisson, also known as the assumption of discs or so-called modified biplane Simpson's formula, $8(A_1)(A_2)/3\pi(L)$. A_1 and A_2 represented the planimetered LA area acquired from the apical four- and two-chamber views, respectively, and L was the shorter of the long axis in both planes,[6] then we indexed the LA volume by individual body surface area. Based on the recommendations of the American Society of Echocardiography (ASE), LA enlargement was defined as LA volume index > 28 ml/m^2.[6]

Standing chest posterior-anterior films of each subject within 1 month of the echocardiography examination were reviewed. Subcarinal angles were measured on the Picture Archive Communication System as described by Turner, along the inferior borders of the bilateral main bronchi to their point of intersection.[7]

The measurements were expressed as the mean ± SD. Subcarinal angles were compared by two-sample Student's t-test between the LA enlargement and non-LA enlargement groups. Simple linear regression was applied to build the model of LA volume index predicted by subcarinal angle. Receiver operating characteristic (ROC) curve was drawn to ascertain an optimal cut-off point for detecting LA enlargement. A p value below 0.05 was considered statistically significant for all analyses. The statistical software used was Stata 9.

RESULTS

The baseline characteristics for all subjects are shown in Table 1. Subcarinal angles were 69.4 ± 11.8° (36.6-112.9°), and LA volume indexes were 38.2 ± 20.1 ml/m^2 (10.3-187.9 ml/m^2). There were 252 subjects in the LA enlargement group and 124 subjects in the non-LA enlargement group. Subcarinal angles in the LA enlargement group and the non-LA enlargement group were 70.6 ± 12.0° and 66.9 ± 11.1°, respectively. We established p = 0.0035 by two-sample Student's t-test, which indicated that subcarinal angles differed significantly between these two groups.

To elucidate the relationship between LA volumes and subcarinal angles, we first drew a scatter plot for LA volume indexes and subcarinal angles. Then we analyzed it by simple linear regression. There was a significant positive correlation between subcarinal angles and LA volume indexes (r = 0.41, p < 0.001) (Figure 1).

Table 1. Baseline characteristics of the 376 subjects

Gender (male/female)	171/205
Age (years old)	67.3 ± 16.4 (15-96)
Hypertension (n, %)	256 (68.1)
Atrial fibrillation (n, %)	34 (9)
Mitral valve stenosis (n, %)	4 (1.1)
LA volume (ml)	61.6 ± 32.4 (17.1-325.9)
LA volume index (ml/m^2)	38.2 ± 20.1 (10.3-187.9)
Subcarinal angle (°)	69.4 ± 11.8 (36.6-112.9)

LA, left atrial.

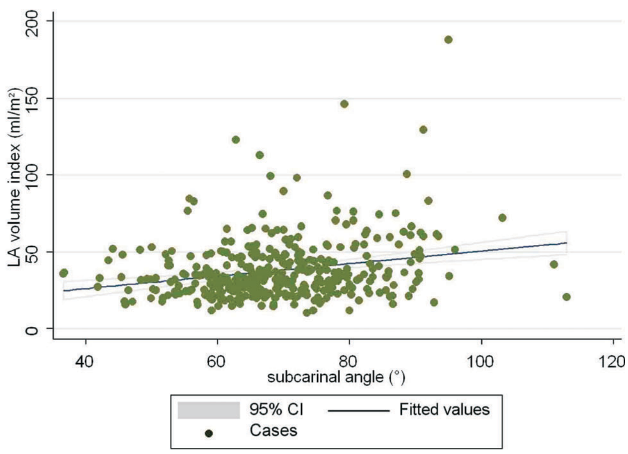

Figure 1. Linear regression analysis showed a significant correlation between subcarinal angle and LA volume index (r = 0.41, p < 0.001).

With the definition of LA enlargement as LA volume indexes > 28 ml/m^2, we checked whether subcarinal angles could act as a satisfactory diagnostic tool to differentiate LA enlargement. We transformed subcarinal angles from a scale variable to an ordinal variable from 36° to 113°. Then we calculated the sensitivity and specificity values of each subcarinal angle (Table 2) and then plotted them into the ROC curve (Figure 2). The area-under-curve of the ROC curve was 0.6024, and the outline was remarkably flat. These findings implied subcarinal angles might not be a satisfactory tool to discriminate LA enlargement.

Since the textbook indicated that subcarinal angle greater than 90° may be pathologic, we tested how well that value was in diagnosis of LA enlargement.[8] With the cut-off point of subcarinal angle as 90°, we found its sensitivity, specificity, positive predictive value, negative predictive value, overall accuracy to be 6.7%, 98.4%, 89.5%, 34.2% and 37.0%, respectively. These parameters suggested subcarinal angles might be an unreliable tool to diagnose LA enlargement.

DISCUSSION

In recent study by using real-time three-dimensional echocardiography, Lin et al. confirm phasic LA volume increase with normal aging.[9] However, LA enlargement is more frequently recognized as a consequence of pathologic condition such as mitral valve diseases or atrial fibrillation.[10] LA size also has a significant association with left ventricular wall thickness and hypertensive heart disease.[11,12] In numerous studies including the Framingham Heart Study and Strong Heart Study, relationships exist between increased LA size and the incidences of atrial fibrillation, as well as ischemic stroke.[13-15] Besides, LA volume is a powerful predictor of prognosis after acute myocardial infarction.[16] In patients with ischemic cardiomyopathy as well as dilated cardiomyopathy, LA volume is an independent predictor of prognosis.[17,18] In addition to above clinical significance, LA enlargement is a strong marker of both the severity of diastolic dysfunction and the magnitude of LA pressure.[19]

Conventional assessment of LA size is chiefly done by m-mode measurement of the LA dimension. However, it can not accurately represent true LA volume because LA expansion in the anteroposterior dimension is limited by physical constraints of the spine and the sternum. LA usually expands more laterally than anteroposteriorly.[20] The most accurate modality to measure LA volume is cine computed tomography (CT), because it is independent to chamber orientation and has higher spatial resolution. This method has been generally considered superior than echocardiography since the boundaries of LA cavity are well delineated. Calculation of

Table 2. List of sensitivity and specificity of different cut-off points for subcarinal angle in discriminating LA enlargement (as LA volume index > 28 ml/m^2)

Cut-off point (°)	Sensitivity	Specificity
≥ 36	100.00%	0.00%
≥ 42	99.21%	0.81%
≥ 48	97.22%	4.03%
≥ 54	92.06%	10.48%
≥ 60	84.13%	24.19%
≥ 66	63.89%	50.81%
≥ 72	43.25%	69.35%
≥ 78	25.40%	86.29%
≥ 84	13.89%	92.74%
≥ 90	6.74%	98.39%
≥ 96	1.19%	99.19%
≥ 102	0.79%	99.19%
≥ 108	0.40%	99.19%
≥ 113	0.00%	100.00%

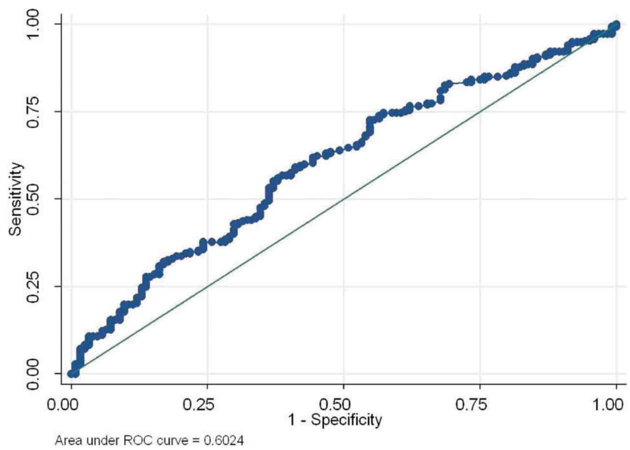

Figure 2. *Non-convex ROC curve implied there was optimal cut-off value of subcarinal angle that discriminated LA enlargement that was defined by LA volume index over 28 ml/m^2. An area under the ROC curve close to 0.5 also implied poor performance in differentiating LA enlargement.*

the LA volume by two-dimensional echocardiography made from the application of a modified Simpson's algorithm has the advantage of being noninvasive, easy performed, and repeatable. But validation of this method should be taken into consideration. Previously published papers had proved there was a good correlation between echocardiography-measured LA volumes and contrast angiography-measured LA volumes.[21] Some studies showed a good agreement between echocardiography-measured LA volumes and CT-measured LA volumes.[22] If we regard CT as the gold standard, the validity of modified biplane Simpson's algorithm remains excellent.

In a study among healthy population, the mean value of subcarinal angle on the upright postero-anterior chest radiography was about 57.16° with a standard deviation of 6.06° for adults.[23] The upper limits of normal tracheal bifurcation angle had been shown to vary widely. Ninety-five percent of normal values were in the range of 45-89° in the study by Alavi et al. compared with 40-80° in the study by Haskin et al.[23,24] Age and gender did not appear to have an influence on the bifurcation angle.[23,24] There was no significant correlation of the carinal angle to either the transverse or sagittal diameter of the thorax.[25] Body mass index also did not show a significant correlation with subcarinal angle.[25]

Taskin et al. first correlated tracheal bifurcation angle on chest X-ray with echo-measured LA size, and the result was significant ($p < 0.01$). They declared that LA dimension could be correctly predicted to be larger than 50 mm if the bifurcation angle was 100° or greater. Even though the angle greater than 90° was an acceptable predictor of LA enlargement.[26] Conversely, Murray et al. reported that correlation between the subcarinal angles and LA dimensions was poor. They disclosed a considerable degree of overlap in the range of bifurcation angles in patients with normal and dilated LA. It was concluded that widening of the tracheal bifurcation angle on chest X-ray was insensitive and of little value in diagnosing LA enlargement.[5] However, above two studies were based on LA dimension measured by M-mode echocardiography. Another study, by means of CT scan, Karabulut et al. correlated subcarinal angles and LA volumes in 120 patients.[25] They found a positive correlation between CT-measured subcarinal angles and LA volumes ($p < 0.001$). But their article mentioned that tracheal bifurcation angles ranged widely in normal subjects, and absolute measurements of this angle were of little diagnostic interest.[25]

Review the past literatures, to our knowledge, our study is the first study which used echocardiography-measured LA volumes to correlate with subcarinal angles. Our results were similar with those done by Karabulut et al.[25] There was a significant positive correlation between subcarinal angles and LA volumes. Although the specificity was high, the relatively low sensitivity and low negative predictive value suggest that subcarinal angle on X-ray radiographs could not serve the purpose of being a screening test for LA enlargement. Even though our study supported the concept that "the larger subcainal angle, the larger LA", this radiological sign has limitations in the diagnosis of LA enlargement.

LIMITATIONS

The carina is a dynamic structure; phase of respiration may affect tracheal carinal angle. It has been known that the carina is displaced downward during inspiration.[27] Elongation of the respiratory tree by inspiration and extension of the head will narrow the subcarinal angle. On the contrary, shortening of the respiratory tree widens the angle. This variable was not well controlled in this study.

The subjects enrolled were selected from examinees of the same sonographer. So the inter-observer variability could be neglected. However, we cannot offer intra-observer variability because the LA volumes data were obtained only by one measurement, as well as the subcarinal angle calculation.

CONCLUSION

Our study demonstrated the subcarinal angle on the chest radiographic film had a significant correlation with echocardiography-estimated LA volumes. Although subcarinal angles had favorable specificity, it lacked sensitivity. Both the positive and negative predictive values were also disappointing. Subcarinal angles provided suboptimal accuracy in predicting the presence of LA enlargement. We were unable to find a cut point for the subcarinal angle where one could confidently conclude that the LA volume was normal. Therefore, we should not regard the subcarinal angle as an accurate diagnostic tool in screening LA enlargement.

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