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Effects of Diffuse Hyperaeration on Thorax and Airways

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ABSTRACT

Objective: In this study our purpose was to demonstrate the differences of thorax, trachea and bronch diameters in the normal individuals and in the patients who have diffuse hyperaerated lungs.

Material and Method: We included 200 cases who had thorax CT scans for various reasons. A multislice CT scanner was used for the study. Diffuse hyperaeration was evaluated for each case's thorax CT. Our study group comprised 161 patients with bilateral diffuse hyperaeration while the control group comprised 39 patients without radiologically detectable hyperaeration . Density measurements were done for lungs accepting -910 HU and less as hyperaeration. Statistical analyses was applied to both groups for thorax AP / lateral diameters (thoracic index), trachea lateral /AP diameters (tracheal index), right main bronchus lateral/AP diameters and left main bronchus lateral/AP diameters (bronchial index) using SPSS 16.0. Mann-Whitney U test was used for comparison the two groups.

Results: There was significant discrepancy between two group's thoracic index, tracheal index and bronchial index measurements ($p<0.05$). ROC analysis showed that treshold value for thorax is 0,825. The patients with increased thorax AP diameters within the control group had higher median ages, concluding age has an effect on the increased thorax AP diameter.

Conclusion: Thoracic index is effected by hyperaeration. Hyperaeration cause saber sheath trachea configuration. Thoracic index values of 0.825 and higher favor increased thoracic AP diameter.

Key Words: *Computed tomography, Computer-assisted image processing, Saber sheath trachea.*

ÖZET

Diffüz Havalanma Artışının Toraks ve Hava Yolları Üzerindeki Etkileri

Amaç: Bu çalışma ile normal bireylerde ve akciğerlerinde diffüz havalanma artışı bulunan hastalarda bronş, trakea ve toraks çap değerlerindeki değişimi oransal olarak ortaya koymayı amaçladık.

Gereç ve Yöntem: Değişik nedenlerle toraks BT çekilen 200 hasta çalışma grubuna alındı. Çalışmada çok kesitli BT kullanıldı. Her toraks BT havalanma artışı yönünden değerlendirildi. Çalışma grubumuz 161 hastadan kontrol grubumuz ise radyolojik olarak diffüz havalanma artışı saptanmayan 39 hastadan oluşmaktaydı. -910 HU ve daha düşük dansite değeri ölçümü havalanma artışı olarak kabul edildi. Toraks AP / lateral çap oranı (torasik indeks), trakea lateral / AP çap oranı trakeal indeks, sağ ve sol ana bronşta lateral / AP çap oranları ise bronşial indeks değerleri SPSS 16.0 paket programı ile istatistiksel olarak değerlendirildi. Gruplar arası karşılaştırmalarda ise Mann-Whitney U testi kullanıldı.

Bulgular: Her iki grubun trakeal indeks, torasik indeks ve bronşial indeks değerleri arasında anlamlı farklılık saptandı. ROC analizi toraksta (AP çap artışı için) eşik değerin 0.825 olduğunu gösterdi. Havalanma artışı olanlarda toraks çap oranının 0,825'in üzerinde olma ihtimali 2,5 kat artmaktadır . Toraks AP çapı artmış kontrol grubu hastalarda ortalama yaş daha yüksek olup yaşın toraks AP çap artışında etkili olduğunu gösterildi.

Sonuç: Torasik indeks hiperaerasyondan etkilenmektedir. Havalanma artışı, kılıç kını trakea konfigürasyonuna yol açmaktadır. 0.825 ve üzerindeki torasik indeks değerleri toraks AP çap artışı ile uyumludur.

Anahtar Kelimeler: *Bilgisayarlı tomografi, Bilgisayar yardımlı görüntü işleme, Kılıç kını trakea.*

Chronic obstructive pulmonary disease (COPD) is a progressive disease which is characterized with irreversible airflow blockage. Airflow blockage is generally related with the abnormal pulmonary inflammatory response given to various kinds of gas and particles. The inflammation of the airways ends up with chronic bronchitis whereas the inflammation of the pulmonary parenchyma with emphysema (1).

Even though the average diameters of trachea and bilateral main bronchus are previously demonstrated within the normal individuals, the AP-to-lateral diameter ratio of the thorax is unknown in the normal population. As a consequence instead of a quantitative manner, the increase in the AP diameter of the thorax is being reported relatively.

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Increased anterior-posterior (AP) diameter of the trachea also known as the "saber-sheath" configuration is reported in the COPD patients in the literature. The 95% of the patients with saber-sheath trachea are reported to have COPD as well (2-5). Increased intrathoracic tracheal diameter is a consequence of compression of the mediasten and lateral walls of the trachea by increased volume of the both lungs. The increased AP diameter of the thorax is also known to accompany the hyperaeration of the lungs (6).

In this study our purpose is to demonstrate the AP-to- lateral diameter ratio of the thorax as thoracic index, tracheal index and bronchial diameters in the normal individuals as well as in the patients who have diffuse hyperaerated lungs.

MATERIAL AND METHOD

We included 200 cases who had thorax CT scans for various reasons. We excluded the patients who radiologically had focal or unilateral hyperaeration, patients with pleural or parenchymal pathologies, patients who has pulmonary embolism which causes increase in radiolucency due to hypovascularization or primary pulmonary hypertension and cardiac oligemic cases. Every patient's thorax CT was interpreted for excluding any pathology in their either trachea or bilateral bronchus. We adhered to Helsinki declaration and written consents were taken from every patients included in the study. Our instutional ethics board has approved the study.

A multislice CT scanner (64 slice Toshiba Aquilion, Chicago, USA) was used for the study. CT was performed on a 64-row detector scanner at 120 kVp, 155 mA during inspiration covering from the apex to the basal segments of the lungs with contrast iodine injection in supine position. The slice thickness was 1 mm with 0.5 mm slice gap.

Air trapping was evaluated for each case with thorax CT. Our study group comprised 161 patients with bilateral diffuse hyperaeration while the control group comprised 39 patients without radiologically detectable hyperaeration. Density measurements were done for lungs accepting -910 HU and less as hyperaeration (7). Bilateral flattened diaphragm or lower position of the diaphragm, retrosternal and intercostal widening promoted diffuse hyperaeration as well.

The measurements were done semi-automatically via the already existing work station's computer programs. AP and lateral thoracal diameters were measured at heart's maximum transverse diameter level. Bones were included in the measurements of thoracal AP and lateral diameters (Figure 1).

Figure 1. *Axial CT slice shows the measurement of thorax AP and lateral diameters.*

Trachea's lateral and AP diameters were measured 2 cm proximal to the carina whereas main bronchus diameters (AP and lateral) were measured 1.5 cm distal to carina level. Coronal multiplanar reformatted (MPR) images were used to measure trachea's diameters (Figure 2a, 2b). An arrow has been replaced 2 cm proximal to trachea where lateral diameter was measured in coronal plane as well as AP diameter in axial plane. Coronal MPR images were used to measure bilateral bronchus diameters (Figure 2c, 2d). Lateral diameter of right main bronchus was measured in coronal plane 1.5 cm distal to carina and this level was marked with an arrow as well as right main bronchus AP diameter in the axial plane. Lateral diameter of left main bronchus was measured in coronal plane 1.5 cm distal to carina and this level was marked with an arrow as well as left main bronchus AP diameter in the axial plane.

Figure 2a. *Trachea lateral diameter measurement on coronal MPR image.*

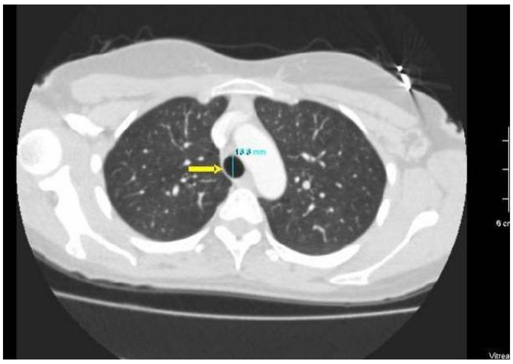

Figure 2b. *Trachea AP diameter measurement on axial CT image.*

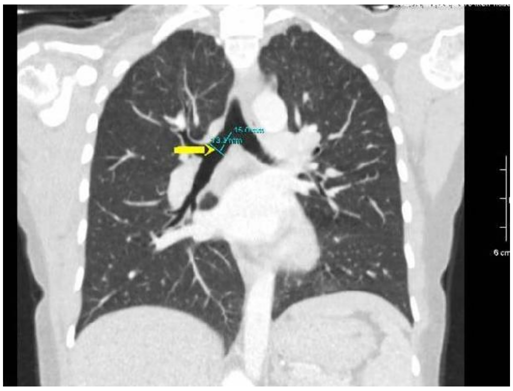

Figure 2c. *Right main bronchus lateral diameter measurement on coronal MPR image*

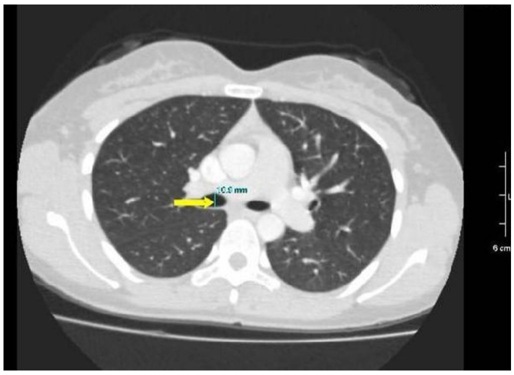

Figure 2d. *Right main bronchus AP diameter measurement on axial CT image*

Patients in both study and control group were evaluated for age, sex and thorax CT findings. Statistical analyses was applied to both groups for thorax AP/lateral diameters (thoracic index), trachea lateral/AP diameters (tracheal index), right main bronchus lateral/AP diameters and left main bronchus lateral/AP diameters (bronchial index) using SPSS 16.0. Mann-Whitney U test was used to find if there was significant discrepancies between two group's trachea, right and left main bronchus diameter ratios (Table 1). Logistic regression analysis was also applied to find out the effect of age among the control group patients with increased thoracic index.

Table 1. *Comparison between two groups' thoracal index, tracheal index and two main bronchus bronchial index with Mann-Whitney U test*

	Group	n	Mean	Median	Min	Max	SD	Mann-Whitney U	p
Thoracic index	Control	161	0,82	0,8	0,64	1,12	0,09	2361,5	0,016
	Study	39	0,88	0,83	0,67	1,18	0,15		
Tracheal index	Control	161	1,086	1,1	0,55	1,46	0,155	1128	0,000
	Study	39	0,806	0,79	0,48	1,35	0,227		
Bronchial Index (right)	Control	161	1,20	1,17	0,96	2,05	0,15	1680,5	0,000
	Study	39	1,07	1,07	0,81	1,27	0,13		
Bronchial Index (left)	Control	161	1,15	1,13	0,85	1,65	0,12	2345	0,014
	Study	39	1,08	1,1	0,79	1,3	0,13		

RESULTS

The control group's average thoracal index was 0,82, tracheal index was 1.14, right bronchial index was 1,19, left bronchial index was 1,14 whereas the study group's average thoracic index was 0,88, tracheal index was 0,80, right bronchial index was 1,06, left bronchial index was 1,08 (Table 2).

There was significant discrepancy between two group's thoracic, tracheal and bronchial index ($p<0.05$). The threshold was statistically significant due to its p value 0,016 (<0,05). Chi-square test was used to evaluate the presence of significant discrepancy of the the threshold values between two groups. Chi-square=6,969, Sd=1, p=0,008, <0,05 ROC analysis showed that threshold value for thorax is 0,825. Based on this value positive predictive value is 56,4% and negative predictive value is 66.5% . There was significant discrepancy between two group's threshold values (p<0,05).

Table 2. *Age, sex, mean thoracal index, mean tracheal index, mean bronchial index and saber sheath percentages of two groups*

	Control Group	Study Group
Age (mean)	54	62
Male	92	32
Female	69	7
Mean thorax AP/lateral diameter (thoracic index)	0,82	0,88
Mean tracheal lateral/AP diameter (tracheal index)	1,14	0,80
Mean right main bronchus lateral/AP diameter (bronchial index)	1,19	1,06
Mean *left* main bronchus lateral/AP diameter (bronchial index)	1,14	1,08
Saber sheath trachea	% 0,62	% 30,7

Thoracic index was found >0,825 in 56.4% and <0,825 in 43.6% of the hyperaerated cases(n=39). The thoracal index was >0,825 in 33.5% within the control group (n=161). The risk of AP / lateral diameter ratio >0,825 was 2,5 times greater in the hyperaerated group (Figure 3a, 3b).

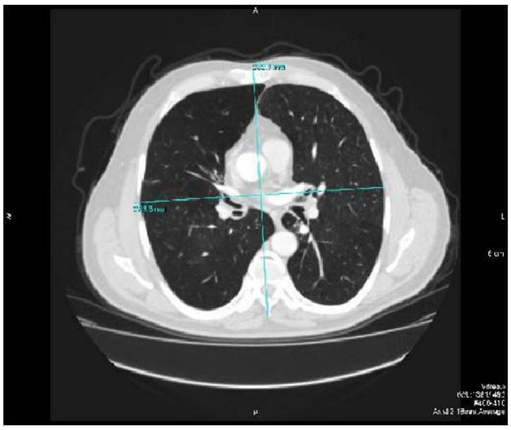

Figure 3a. *Axial CT slice of a 62 years old male patient with diffuse hyperaerated lungs. Thoracic index (thorax AP/lateral diameter ratio) in this patient was increased (0.98).*

Figure 3b. *Axial CT slice in the same patient shows increased trachea lateral/AP diameter(tracheal index as 0.55, saber-sheath trachea)*

Logistic regression analysis was applied to find out the effect of age among the control group patients whose thorax diameter ratios were greater than 0,825. We didn't find any significant discrepancies when comparing the median and mean ages of the study group's patients with or without increase in thorax AP diameters. However, the patients with increased thorax AP diameters within the control group had higher median and mean ages, concluding age has an effect on the increased thorax AP diameter.

Only one of the 161 patients comprising the control group had a thoracic index less than 0,6. 12 patients of 39 patients (30,7%) within the study group had saber-sheath trachea.

DISCUSSION

There are studies circulating around the patients with the saber-sheath configuration of the trachea which has drawn attention to the increased prevalence of this deformity in the COPD patients. Saber-sheath trachea is a static deformity known with significant decreased lateral and increased AP diameters of trachea. Simmonds was the first to describe it on the cadavers as "saber-sheath trachea of the elders". The studies paid attention to the coexistence of saber-sheath trachea deformity with the COPD (8-11). There are a few mechanisms thought to be responsible. Intrathoracic tracheal diameter decreases with expiration. The decrease in paratracheal mediasten's potential lateral diameter with trapped air has been debated to cause this deformity (9, 11). COPD patients are effected more from decrease in diameter. Another theory is tracheal ring degeneration, vascularization and ossification causing the deformity. It might be an abnormal remodeling of the damaged trachea. Also recurrent coughing causing tracheal degeneration via chronic tracheal collapse or degeneration-remodellation has been reported (8, 9). Previous studies described saber-sheath trachea as lateral/AP diameter of trachea less than 0,6 (9, 12). It is important to know the presence of saber-sheath trachea to avoid complications due to intubation of mechanical ventilation.

Greene et al. (9) showed coexistence of COPD within the 95% of the saber–sheath trachea patients. Our study demonstrated hyperaeration in 12 patients (92,3%) within the 13 saber-sheath trachea deformity which is compatible with Greene et al. The only case who didn't show hyperaeration was a 74 y/o male saber-sheath trachea patient with increased thoracic AP diameter. All the saber–sheath trachea patients found in our study were male. As though it is known as a deformity affecting almost only male population (12).

Our study radiologically demonstrated increased thorax AP diameter and AP/lateral diameter ratio within the diffuse hyperaerated lungs which is compatible with Cassart et al.'s supine CT study's findings and measurements (13). However, previously done standing PA and lateral radiography studies showed no evidence of that (14, 15).

Radiologically it is known that hyperaeration may lead increased thorax diameter (6). Our study showed a threshold value of 0,825 for thoracal index moreover demonstrated increased thorax AP/lateral diameters in 22 (56,4%) patients within the study group.

Many studies demonstrated increased AP diameter with increasing age (16, 17). In 54 (33,5%) patients of our control group's 161 patients hyperaeration wasn't appointed radiologically however increased thorax AP diameter was. 42 of these 54 patients were over 60 y/o. In the control group the average age of patients with thoracic index higher than 0,825 was statistically higher than the patients with thoracic index less than 0,825.

To our knowledge the impact of hyperaeration on the bronchus diameter hasn't been demonstrated previously in the literature. Our study showed bilateral bronchus lateral/AP diameter ratios were affected by hyperaeration as well as trachea diameter.

One of our limitations is the different numbers of patients in control and study groups which prevented us from statistical comparison. Moreover, our study comprised random patients who had different complaints for a routine thorax CT scan. For this reason precisely our control group doesn't comprise only healthy adults which may be the main cause of increased thoracic or tracheal AP diameter. Because recurrent polychondritis, tracheobronchopathia osteochondroplastica, amyloidosis, primary and metastasing tumors, mediastinitis effecting the airways, tracheomalasia are also known possible causes of tracheal narrowing (18).

In conclusion thorax AP/lateral diameter ratio is affected by hyperaeration. Thorax AP/lateral diameter ratio's threshold is found to be 0.825 and the higher values should favor increased thoracic AP diameter. Tracheal lateral/AP diameter ratio is affected by the hyperaeration. Bilateral main bronchus lateral/AP diameter ratio is affected by hyperaeration.

Particularly in elder patients saber-sheath trachea and increased thoracic AP diameter can be observed radiologically.

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