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Volumetric study of tracheal diverticulum: a retrospective analysis in computed tomography

Enes Gürün[1], İsmail Akdulum[2], Mustafa Kaya[2]

[1]İskilip Atıf Hoca State Hospital, Department of Radiology, Çorum, Turkey
[2]Gazi University, Department of Radiology, Ankara, Turkey

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ABSTRACT

Aim: The aim of this study was to retrospectively evaluate the prevalence and morphology (location, diameter, number and volume) of the tracheal diverticulum (TD) on thoracic computed tomography (CT), in a sample of the Turkish population.

Material and Method: The study was conducted over 15 months, from February 2020 to April 2021, and included 3,860 thoracic CT scans, of which 1,891 subjects were men and the rest were women. All of the thoracic CT scans were evaluated retrospectively. All images were reviewed for the presence or absence of the TD in the axial plane, defined as air sacs around the trachea and communication with the trachea. For volume measurement, the TD contour was manually evaluated by a single radiologist, for all patients. Descriptive statistics were reported as mean±standard deviation (SD). A p value of less than 0.05 was considered significant.

Results: The mean age of the patients was 57.87±14.76 (29-84). In this study, the incidence of TD was calculated to be 0.80%. The mean tracheal diverticulum volume (TDV) and maximum transverse diameter (MTD) of TD were 983.62±1 509.80 mm³ and 8.79±6.19 mm, respectively.

Conclusion: In this study, we demonstrated the volumetric measurement of TD and its prevalence. We believe that the frequency of its use in clinical practice should increase, as volumetric measurements provide healthier results than diameter measurements.

Keywords: Volumetry, tracheal diverticula, prevalence, computed tomography

INTRODUCTION

A tracheal diverticulum (TD) is usually asymptomatic and is detected incidentally during imaging procedures, such as thoracic computed tomography (CT). When TD is symptomatic, it can cause respiratory symptoms such as cough, dyspnea, stridor and hemoptysis (1). It may also present with infection, abscess and rupture (2,3). TD is described as thin-walled air sacs in the paratracheal wall, often in contact with the tracheal lumen (4). TD is divided into 2 subgroups: congenital and acquired (5). Congenital TD is more common in males than females and is located 4 to 5 cm inferior to the vocal cords. Congenital TDs are thought to be caused by a developmental defect in the tracheal cartilage (6), whereas acquired TDs occur due to tracheomalacia or surgical complications. Acquired TD may occur as a result of increased intraluminal pressure due to chronic obstructive pulmonary disease (COPD). They are often located in the posterolateral of the trachea, at the level of the thoracic inlet. In addition, acquired TDs are often larger than congenital TDs (4).

CT is an important tool for the evaluation of the TD and the visualization of other associated pathologies (7,8). CT can be used to assess the location, volume, contour, and wall thickness of the TDs (9). It can also detect communication between the TD and the trachea (5). The TD is often located in the right posterolateral aspect of the trachea and less commonly on the left side (1,4).

The aim of this study was to retrospectively evaluate the prevalence and morphology (location, diameter, number and volume) of the TD on thoracic CT, in a sample of Turkish population.

Corresponding Author: Enes Gürün, e.grn06@gmail.com
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MATERIAL AND METHOD

The study was carried out with the permission of Hitit University Non-interventional Researchs Ethics Committee (Date: 28.06.2021, Decision no: 2021-73). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Informed consent was waived due to the retrospective nature of the study, as well as the fact that the assessment utilized anonymous research findings. The study was conducted over a period of fifteen months, from February 2020 to April 2021. Many of the patients had respiratory symptoms, such as chest pain, shortness of breath and cough, while others had no symptoms of respiratory problems but were routinely screened for various diseases, such as pulmonary nodules. Patients who did not have acceptable image quality on the computed tomography scans and medical records were not included in the study.

CT studies were performed using a multidetector 16-row helical CT scanner (Alexion, Toshiba Medical Systems, Nasu, Japan). The CT imaging was performed during a breath-hold at deep inspiration. Spirometric gating was not applied. The scans were obtained from the base of the neck down to the diaphragm. A supine or prone position was chosen. Parameters were 100–120 Kv, the field of view was 350 millimeters (mm), beam collimation was 1×16 mm, gantry rotation time was 0.5 seconds and scan time was 11–13 seconds. Thin-section CT data were reconstructed at a slice thickness of 1 mm with 0.8 mm intervals. Image matrix size was 512×512. We used automatic tube-current modulation at a maximum of 225 mAs for exposure dose reduction. All CT examinations were performed without contrast media.

All of the thoracic CT scans were evaluated retrospectively. All the images were reviewed for the presence or absence of the TD in the axial plane, defined as air sacs around the trachea and communication with the trachea (**Figure 1**). When TDs were observed, the imaging characteristics (emphysema or bronchiectasis), including location (right or left), size (axial diameter and volume) of all cases were noted. Bronchiectasis was defined as present when the diameter of the bronchial lumen was larger than the adjacent pulmonary artery, with no taper in the diameter of the bronchial lumen. Emphysema was defined as small, well or poorly-defined areas of low attenuation, surrounded by normal lungs.

The volume of TDs was analyzed using a Vitrea workstation (Canon Medical Systems Corporation, Otawara, Japan) by a single radiologist (E.G.), with seven years of experience in thoracic radiology. For volume measurement, the TD contour was manually evaluated by the examiner, for all patients. The area in each slice was then recorded and the volumes were measured automatically by the Vitrea post-processing imaging software (Canon Medical Systems Corporation, Otawara, Japan). Finally, the volume was measured by the software and a three-dimensional reconstruction of the organ was generated (**Figure 2**). The tracheal diverticulum volume (TDV) was measured in milliliters (ml) or cubic millimeters (mm^3): 1 ml was considered as 1 000 mm^3. The TD was re-evaluated 5 days after the initial evaluation to assess reproducibility by the same observer.

Statistical Analysis

Statistical analysis was performed using the SPSS v.22 package program (IBM SPSS Statistics, Chicago, IL, USA). The age, gender and radiological characteristics of the participants were noted. Descriptive statistics were reported as mean±standard deviation (SD). The distribution of the data was analyzed using the Kolmogorov-Smirnov test and the relationship between TDV and gender was analyzed using the Mann-Whitney U test. Whether there is a statistically significant difference between the ages of men and women was also examined using the Mann-Whitney U test. The relationship between TDVs and age, and maximum transverse diameter (MTD), was calculated using "Spearman's correlation coefficient test". The "intraclass correlation coefficient (ICC) test" was used to analyze intraobserver reliability, for repeated measurements with a 95% confidence interval. The ICC was indicated as follows: below 0.50: poor; between 0.50 and 0.75: moderate; between 0.75 and 0.90: good; above 0.90: excellent. A p value of less than 0.05 was considered significant.

RESULTS

From February 2020 to April 2021, 3,926 adult patients (> 20 years) underwent thoracic CT examinations at our institution. After excluding 49 patients with diagnostically unacceptable image quality resulting from artifacts, and an additional 17 patients without medical records, the thoracic CT examinations of 3,860 adult patients were finally included in this study (1,891 male, 1,969 female) (**Table 1**).

The mean age of the patients was 57.87±14.76 (29-84). There was no statistically significant difference between the ages of men and women (p=0.091). A total of 46 diverticula were detected in 31 patients (17 male, 14 female). In this study, the incidence of TD was calculated to be 0.80%, all of the TDs were located on the right posterolateral side of the trachea and the prevalence of TD in males and females was 0.89% and 0.71%, respectively. The mean TDV and MTD of TD were 983.62±1509.80 mm^3 and 8.79±6.19 mm, respectively. Descriptive statistics are presented in **Table 2**.

A positive moderate correlation was observed between age and MTD (rho: 0.317; p: 0.032) and volume (rho: 0.327; p: 0.027). There was no statistically significant relationship between gender and mean TDV and MTD (p 0.05).

Intraobserver reliability for repeated measurements yielded an overall ICC of 0.935 (0.921-0.951), with a 95% confidence interval.

Table 1. Flowchart shows study population and patient selection process

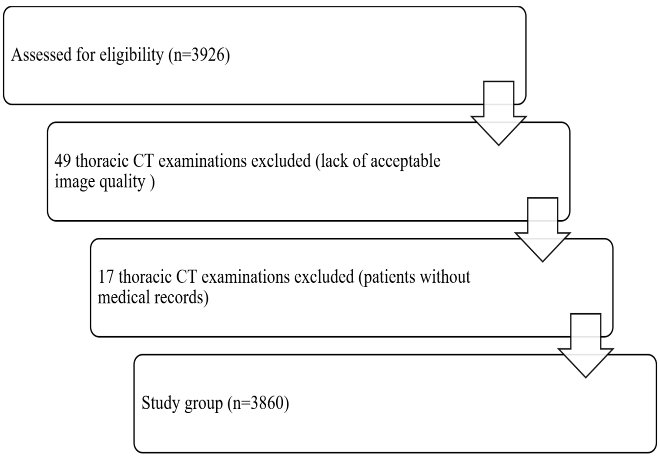

Table 2. Descriptive statistics for age, MTD of TD, Mean TDV and gender distributions of all cases

Variables	Total (n=31)
Age (year old)	57.87±14.76 (29-84)
MTD of TD (mm)	8.79±6.19 (2-30)
Mean TDV (mm³)	983.62±1509.80 (20.95-6401.24)
Gender (M/F)	17/14

Data is expressed as n (number) or the mean± standard deviation (range). F: Female, M: Male, MTD: maximum transverse diameter, TD: Tracheal diverticulum, TD: Tracheal diverticulum volume, ml: milliliters, mm³: cubic millimeters

DISCUSSION

TDs are air spaces lined with ciliary columnar epithelium and connected to the trachea. Despite the fact that autopsy studies report a prevalence rate of 1%, the prevalence of TDs has been reported as high as 8.1% in previous radiological studies. It is divided into two groups: congenital and acquired (4,5). Acquired or congenital diverticula can be distinguished along with the location of the diverticulum, the age of the patient, the size of the diverticulum and the neck of the diverticulum (10). TDs are usually asymptomatic and are detected incidentally in thoracic CT. Possible symptoms include airway obstruction, recurrent lower respiratory tract infections, mass effect dysphagia, hoarseness, gagging and hemoptysis (4).

The associations between underlying lung diseases, such as emphysema or COPD and the prevalence of TDs, are still controversial. Goo et al. (7) and Boyacı et al. (11) reported an association between COPD and paratracheal air cysts (PTACs). In a study conducted by Polat et al. (12) on 301 patients with PTACs, they found no association between COPD and PTACs. In the study conducted by Cheng et al. (13), no association either was found between COPD and PTACs.

The prevalence of TD has been reported to range from 0.75% to 8% in previous studies (1, 11). In some of these studies however, true diverticula were not differentiated

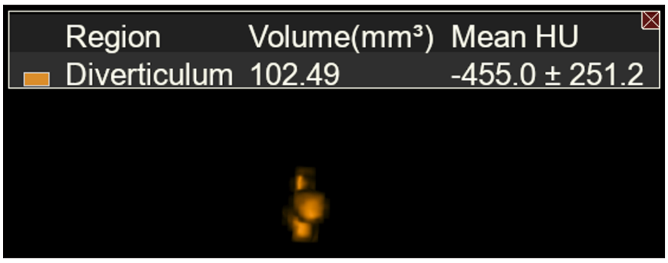

Figure 2. Calculation of TDs volume and three-dimensional reconstructed CT image of its.

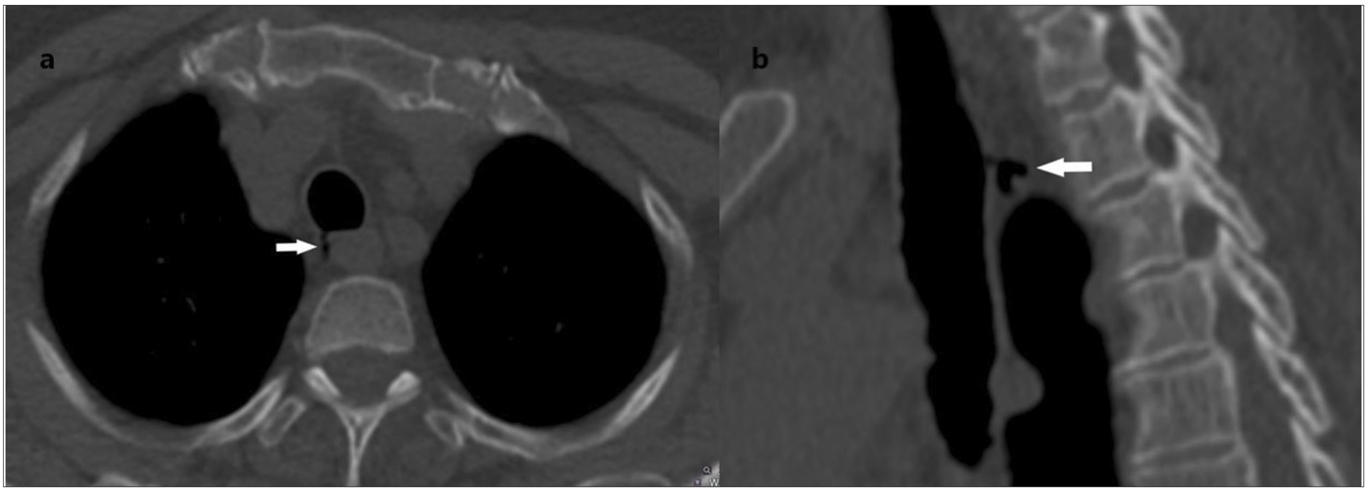

Figure 1. Non-contrast thoracic CT image in the axial **(a)** and sagittal **(b)** plane, showing TD (white arrow) which was located on the right posterolateral side of the trachea.

according to the presence of a tracheal junction, and PTACs were also included in the studies. In our study, PTACs not connected to the trachea were not included in the study, and true diverticula connected to the lumen of the trachea were included in the study. For this reason, we think that the prevalence of TD in our study was lower compared to previous studies. In the study by Pace et al. (5), 124 TDs were detected in 1,679 CT scans and a prevalence of 5.7% was calculated. Kurt et al. (14) in their study, found 412 TDs belonging to 299 patients. In their study, the prevalence of TD was found to be 2.38%, whereas in our study, the prevalence was calculated as 0.8% (males 0.89% and females 0.71%). We think that the high prevalence that was observed in the study of Pace et al. (5) could be due to the difference in sample groups. The difference in prevalence could be due to the presence of CT scans in our patients to screen for COVID-19 pneumonia. Similar to the study by Pace et al., none of the patients in our series TD had a history of trauma, subcutaneous emphysema, nor visible pneumothorax or pneumomediastinum.

According to previous research, TD has a slight female preference (8,11,15). In contrast to previous studies however, in our study, the male gender was more frequently affected than the female gender, as was also reported by Kurt et al. (14). In general, TDs were found on the right side of the trachea, in accordance with previous studies (5,8). This finding may be explained by the fact that both the esophagus and the aortic arch support the left side of the trachea, in terms of resistance to increasing intratracheal stress. TDs are mostly found at the level of the T2 vertebrae on the right posterolateral side of the trachea, which is the transition zone between the intrathoracic and extrathoracic trachea, and this localization also brings the pressure theory to the forefront, as it is a transition zone (16). In our study, TDs were detected in this localization, in all cases.

Boyacı et al. (11) reported the median size of PTACs to be 5.17×6.60×10.95 mm and Kim et al. (8) reported it as 7.5×4.2×11.5 mm. Goo et al. (7) found a mean axial diameter of 10 mm and a mean vertical length of 14 mm. In our study, the mean TDV and MTD of TD were 983.62±1 509.80 mm³ and 8.79±6.19 mm, respectively. Measurements of diameter may not be accurate due to some variability in the morphology of TD, however volumetric analysis can now provide more standardized evaluations thanks to advances in CT software technology and for this reason, it should be used more widely in practice. Volumetric measurement is important in terms of calculating dimensional size with higher accuracy and predicting potential surgical complications. This is because two-dimensional measurement without three-dimensionality, overlooks the possible difference in volume. In radiological practice, volume measurements are generally obtained by multiplying the diameters, measured in 3 planes by the spherical formula (R1 x R2 x R3 x 0.52). However, for structures with irregular boundaries, errors in volume measurements may occur. In this study, we evaluated the location and volumes of TD, which were detected during thoracic CT examinations in adults. Using the workstation program, the area of each section was calculated separately by the program and volume measurements were performed automatically.

This study has several limitations. First of all, it included only a limited number of patients and was monocentric: future multicenter studies with a larger number of patients will provide more accurate evidence. Second, interobserver reliability could not be assessed because the evaluations were performed by a single radiologist. Finally, our measurements were performed only in vivo and the actual ex vivo volume was not evaluated.

CONCLUSION

We demonstrated with this study the volumetric measurement of TD, as well as its prevalence. We believe that the frequency of its use in clinical practice should increase, as volumetric measurements provide healthier results than diameter measurements.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Hitit University Non-interventional Researchs Ethics Committee (Date: 28.06.2021, Decision no: 2021-73).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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