

Revisiting the morphometry of cricoid cartilage and vocal folds

Plica vocalis ve cartilago cricoidea morfometrelerinin yeniden değerlendirilmesi

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Abstract

Background: Rima glottidis and cricoid cartilage are important parts for laryngeal passage. However, their complex anatomical organizations give rise to occur some difficulties during intubation or surgeries. Therefore, these anatomical structures have great risk of damage during these procedures. The main aim of this study is to evaluate detailed morphometric properties of these critical parts of the larynx.

Methods: In this study, 74 female and 76 male patients', without any pathology in their laryngeal and neck regions, computed tomography images were examined, retrospectively. Anteroposterior diameter of the supraglottic region immediately above the vocal folds, anterior angle of the vocal folds, transverse diameter of the rima glottidis and anteroposterior and transverse diameters of the cricoid cartilage were measured using Osirix-Lite version 9.

Results: Transverse diameter of the cricoid cartilage was found less than 1 cm, however, the transverse diameter of the rima glottidis was significantly smaller. All variables except for anterior angle of the vocal folds were higher in men than women.

Conclusions: The transverse diameter of the rima glottidis was the narrowest part of the laryngeal passage. The physicians should be aware of this part of the larynx besides the cricoid cartilage during endotracheal tube administrations.

Keywords: Adult airway, computed tomography imaging, cricoid cartilage, larynx, vocal folds.

Öz.

Amaç: Rima glottidis ve cartilago cricoidea larynx geçişinin önemli kısımlarıdır. Bununla birlikte, karmaşık anatomik yapılar olmaları sebebiyle entübasyon veya cerrahi sırasında bazı güçlükler yol açabilirler. Bu sebeple, bu işlemler sırasında, bu anatomik yapılar, istenmeyen yaralanmalar açısından oldukça büyük bir risk altındadırlar. Çalışmamızın amacı, larynx'in bu önemli parçalarının morfometrelerinin detaylı olarak incelenmesidir.

Materyal ve Metod: Bu çalışmada, larynx ve boyun bölgelerinde herhangi bir patoloji olmayan 74 kadın ve 76 erkek hastaya ait bilgisayarlı tomografi görüntüleri retrospektif olarak incelendi. Plica vocalis'in hemen üzerinde kalan supraglottic bölgenin anteroposterior çapı, plica vocalis'lerin anterior birleşme açısı, rima glottidis'in transvers çapı ve cartilago cricoidea'nın anteroposterior ve transvers çapları Osirix-Lite version 9 yazılımı kullanılarak ölçüldü.

Bulgular: Cartilago cricoidea'nın transvers çapı 1 cm'den az bulundu, ancak rima glottidis'in transvers çapı cartilago cricoidea'nın transvers çapından anlamlı derecede daha küçüktü. Plica vocalis'in anterior açısı dışındaki tüm değişkenler erkeklerde kadınlardan daha yüksekti.

Sonuç: Rima glottidis'in transvers çapı larynx geçişinin en dar kısmıydı. Endotrakeal tüp uygulamaları sırasında, uygulamayı yapacak olan hekimler cartilago cricoidea'nın yanı sıra larynx'in bu kısmının da farkında olmalıdır.

Anahtar Kelimeler: Erişkin solunum yolları, bilgisayarlı tomografi, cartilago cricoidea, larynx, plica vocalis.

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Geliş tarihi / Received: 01.07.2019

Kabul tarihi / Accepted: 22.07.2019

DOI: 10.35440/hutfd.584919

Introduction

Diabetes mellitus (DM), a serious cause of morbidity and mortality, is a condition that concerns the entire world population. The incidence of DM is increasing day by day. (1, 2). The total number of diabetic patients is expected to be 439 million by 2030 (1). Since DM is a global problem, many investigations to find markers related to disease, complications and prognosis were researched (3, 4, 5).

Diabetic retinopathy (DR) is one of the most feared complications of diabetes. Several researches have been done to estimate the prevalence of DR (6-9). Blindness caused by DM currently affects approximately 15

Introduction
Larynx is an air passage, phonation organ and acting as a sphincter. It is found between the tongue and the trachea and it has complex relations with regard to the respiratory and phonatory functions. Although the morphometry of the laryngeal skeleton significantly alters until puberty, these alterations does not demonstrate statistical differences between genders. However, male larynx enlarges significantly after puberty in comparison with female larynx (1, 2). However, there is no report that evaluating gender differences of the normal glottal configuration in resting position. Cricoid cartilage is the only part of the laryngeal skeleton that surrounding airway and because of its firm formation it is not flexible during the intubation. Therefore, selecting an appropriate endotracheal tube is also important in adult patients. Earlier studies focused on the diameters of the cricoid cartilage in adult patients among various populations (3-5). Their results demonstrated that the larynx has variable morphometric properties among the different populations.

Determining the morphometric properties of the larynx is important and useful for physicians during various protocols such as intubation, endoscopy and surgical managements. Since the morphometric properties of the larynx alter significantly in childhood period of the life, recent studies focused on properties of pediatric larynx. (6-8). These studies described the narrowest parts of the pediatric larynx helping the surgeons during surgical procedures such as endotracheal intubation. It was also reported that selecting an unsuitable endotracheal tube may cause the cartilage damage that leads airway obstruction with laryngeal edema (6).

Upper level of the vocal fold and the rima glottidis are important parts of the larynx that endotracheal tube passes during intubation. According to authors' literature knowledge, rima glottidis was evaluated during various tasks such as speaking, respiration and singing (9-11). Furthermore, glottal configuration was evaluated during the management of the vocal fold pathologies (12-14). The main purpose of our study was to evaluate detailed morphometric properties of the larynx parts that have risk for damage during endotracheal tube administration using computed tomography (CT) images in Turkish population.

The cricoid cartilage and rima glottidis which were under the risk during intubation were evaluated in more detail to achieve this purpose. Our findings would be a useful guide for physicians to pay attention to the other laryngeal structures which comprise the laryngeal passage besides the cricoid cartilage.

Materials and Methods

This study began after the approval from the ethical board of authors' university (decree no. GO 18/877-32).

Patient Selection

In our study, 150 patients (74 females / 76 males) were retrospectively evaluated using three dimensional reconstructed CT images of the head and neck region. Participants were selected among the Turkish population. The mean age of the patients was 55.37 (range: 25 – 82). Patients that had undergone CT for a reason another than larynx pathologies, respiratory disorders and had no history of surgery in the neck region were included in the present study. Patients who had been undergone surgery, had respiratory disorders or any pathology in the neck and larynx regions were excluded. Patients who suffer from the obstructive sleep apnea were also excluded. Furthermore, patients were grouped according to age. There were 12, 19, 14, 43, 45, 15 and 2 patients in age groups 1 (25–30), 2 (31–40), 3 (41–50), 4 (51–60), 5 (61–70), 6 (71–80) and 7 (81–90), respectively.

Image Acquisition

A 64 – detector row dual CT scanner (Somatom Definition, Siemens Healthcare, Erlangen, Germany) was used for CT imaging. Only arterial phase imaging was performed. The protocol was as follows: 64 x 0.6 collimation, 1.4 pitch, 0.5-second rotation time, 100 kV(peak) and with 180 effective mAs. The area between upper mediastinum including ascending aorta and vertex was scanned. The timing of CT was determined by the test-bolus technique. The source images were reconstructed into 1-mm slice thicknesses in axial view, coronal and sagittal images were reformatted. All patients' CT images were obtained from the Picture Archiving and Communication System (PACS) of the authors' University Hospital. All measurements were completed by a twenty-year experienced anatomy professor, a fifteen-year experienced anatomy assistant professor, a six-year experienced anatomy specialist using Osirix-Lite version 9 (Pixmeo, SARL, Switzerland).

Morphometric Parameters

Patients were in the supine position without performing any tasks while all CT procedures were completed. To standardize measurements between patients, inferior margin of the cricoid cartilage and the upper edge of the vocal fold were detected using the soft and bone contrast window of the Osirix-Lite version 9 software. To evaluate the antero-posterior diameter of the supraglottic region at the superior edge of the vocal folds, the distance between the posterior

surface of the thyroid cartilage and the posterior wall of the laryngeal inlet in sagittal sections were measured (Figure 1). The anteroposterior and transverse diameters of the cricoid cartilage were measured at the inferior margin of the cartilage in transverse sections (Figure 2). We also measured the anterior angle between vocal folds in transverse sections. In addition, transverse diameter of the rima glottidis at the point between the respiratory and phonatory parts of the vocal folds in transverse sections (Figure 3).

Statistical Analyses

Statistical analyses were performed using SPSS version 23. All variables were investigated using histograms, probability plots, the Kolmogorov-Smirnov test and the Shapiro-Wilk test to define of their normal distribution or vice versa. Descriptive analyses were presented using the means and standard deviations for all variables. The Student's t-test was used for normally distributed variables, and the Mann-Whitney U test was used for non-normally distributed variables for comparison between genders. The Paired Student's t-test was utilized to compare the diameters each other. While investigating the associations between age and the measured variables, the Spearman's rho test was used to calculate the correlation coefficients and their significance at a 5% Type-I error level. Variables with a p-value of less than 0.05 were considered statistically significant. A one-way ANOVA test was used to compare all morphometric data among the age groups. An overall p-value of less than 0.05 was considered to show a statistically significant result.

Results

The narrowest anteroposterior diameter of the supraglottic region was 1.06 cm. The mean anteroposterior diameters of the supraglottic region were 1.69 ± 0.21 cm (1.06 – 2.22) in women and 2.24 ± 0.33 cm (1.61 – 3.05) in men. Furthermore, the mean value of the transverse diameters of the cricoid cartilage were 1.49 ± 1.03 cm (0.98 – 1.01) in women and 1.79 ± 0.21 cm (1.15 – 2.53) in men. The details of the remainder variables, including their mean values, standard deviations and minimum and maximum values were summarized in Table 1. Morphometric measurements did not demonstrate any significant differences among the age groups ($p > 0.05$). These results demonstrated that the morphometry of the larynx did not affected by the age.

The results of the gender comparisons demonstrated that the anteroposterior diameter of the supraglottic region, anteroposterior diameter and the transverse diameters of the cricoid cartilage, and the transverse diameter of the rima glottidis were greater in men than women ($p < 0.001$), except the anterior angle of the vocal folds which was measured wider in women than men ($p < 0.001$).

The anteroposterior diameter of the supraglottic region im-

mediately above the vocal folds was larger than the anteroposterior diameter of the cricoid cartilage ($p < 0.001$), likewise, the transverse diameter of the cricoid cartilage was longer than the transverse diameter of the rima glottidis ($p < 0.001$). Furthermore, the anteroposterior diameter of the cricoid cartilage was longer than the transverse diameter of the cricoid cartilage ($p < 0.001$). The anteroposterior diameters of the cricoid cartilage and the supraglottic region were larger than the transverse diameter of the rima glottidis ($p < 0.001$).

Table 1. Morphometric measurements (Mean \pm Standard Deviation)

Parameters	GENDER	
	Women	Men
Anteroposterior supra-glottic diameter (cm)	1.69 ± 0.21 (1.06 – 2.22)	2.24 ± 0.33 (1.61 – 3.05)
Anteroposterior diameter of the cricoid cartilage (cm)	1.68 ± 0.16 (1.31 – 2.33)	2.02 ± 0.21 (1.52 – 2.49)
Transverse diameter of the cricoid cartilage (cm)	1.49 ± 1.03 (0.98 – 10.1)	1.79 ± 0.21 (1.15 – 2.53)
Anterior angle of vocal fold (in degree)	$44,76 \pm 9.24$ (25.37 – 72.65)	40.07 ± 10.42 (19.93 – 76.3)
Transverse diameter of rima glottidis (cm)	$0,89 \pm 0.18$ (0.49 – 1.29)	0.98 ± 0.27 (0.14 – 1.64)

As a result of the correlation analyses without considering gender, the anteroposterior diameter of the cricoid cartilage had statistically significant correlation with the age ($\rho = -0.21$, $p = 0.001$, $R^2 = 0.043$). Furthermore, age had a significant effect on the anteroposterior diameter of cricoid cartilage in only men patients ($\rho = -0.29$, $p < 0.05$, $R^2 = 0.088$), while the women's anteroposterior diameter of the cricoid cartilage had no significant correlation with the age ($p = 0.15$) (Figure 4). In addition, the anteroposterior diameter of the supraglottic region had significant correlation with the anteroposterior diameter of the cricoid cartilage among all patients ($\rho = 0.66$, $p < 0.001$, $R^2 = 0.44$) (Figure 5). This significant correlation was caused by the significant correlation in men ($\rho = 0.48$, $p < 0.001$, $R^2 = 0.23$) (Figure 6), while the diameter of the supraglottic region had no significant correlation with the anteroposterior diameter of the cricoid cartilage in women ($p = 0.16$). The anteroposterior diameter of the supraglottic region had a significant correlation with the anterior angle of the vocal fold in all patients ($\rho = -0.21$, $p = 0.01$, $R^2 = 0.041$) (Figure

7). In contrast to this result, there were no significant correlations between the diameter of the supraglottic region and the anterior angle of the vocal fold in men ($p = 0.43$) and women ($p = 0.96$). Furthermore, there was a statistically significant correlation between the anteroposterior and transverse diameters of the cricoid cartilage ($\rho = 0.64, p < 0.001$). However, the anteroposterior diameter of the supraglottic regions ($p = 0.68$), the transverse diameter of the cricoid cartilage ($p = 0.68$), anterior angle of the vocal folds ($p = 0.11$) and the transverse diameter of the rima glottidis ($p = 0.88$) had no correlation with the age.



Figure 1. Anteroposterior diameter of the supraglottic region

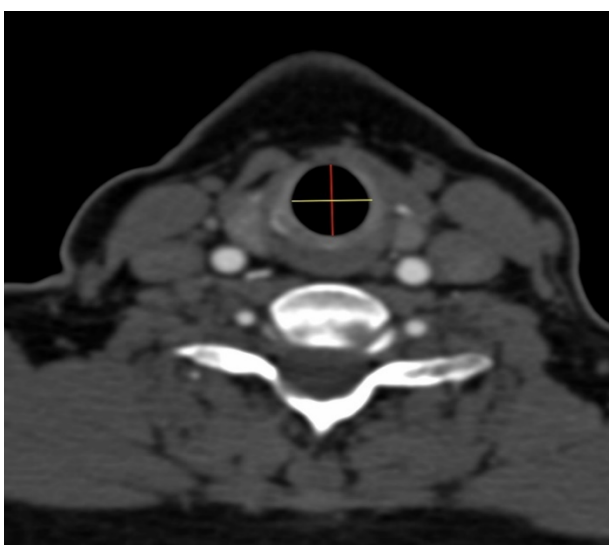


Figure 2. Diameters of the cricoid cartilage; Anteroposterior diameter, red line; Transverse diameter, yellow line.

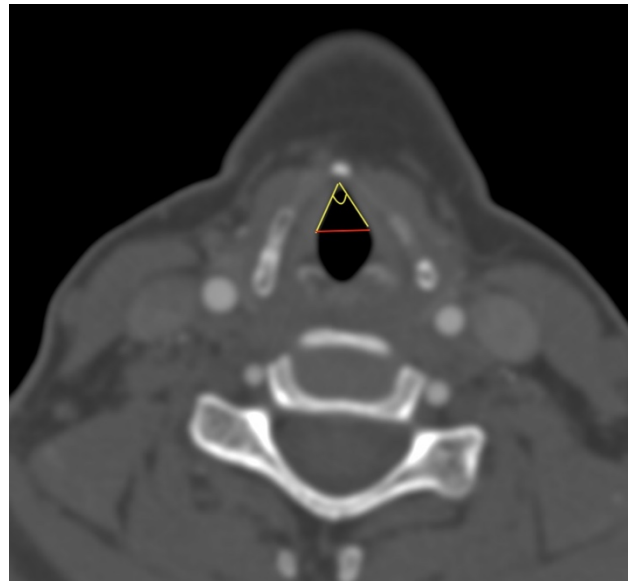


Figure 3. Anterior angle of the vocal folds (yellow line) and transverse diameter of the rima glottidis (red line)

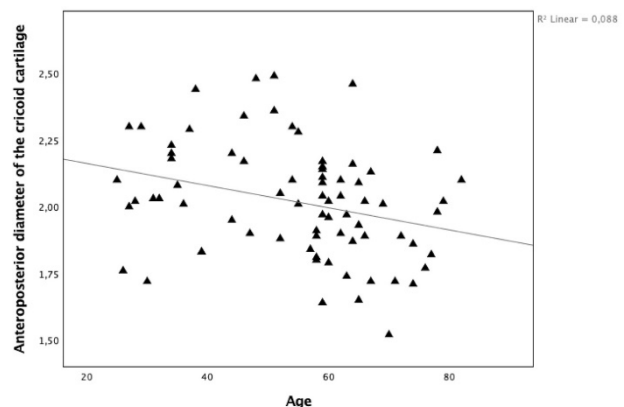


Figure 4. Correlation between anteroposterior diameters of the cricoid cartilage and age in men

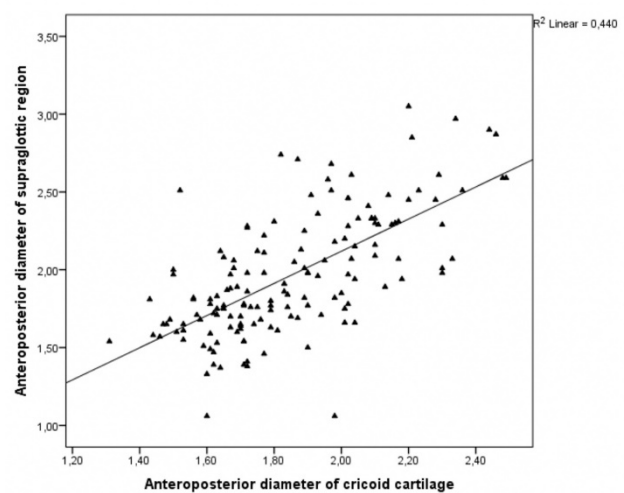


Figure 5. Correlation between anteroposterior diameters of the supraglottic region and the anteroposterior diameter of the cricoid cartilage in all patients

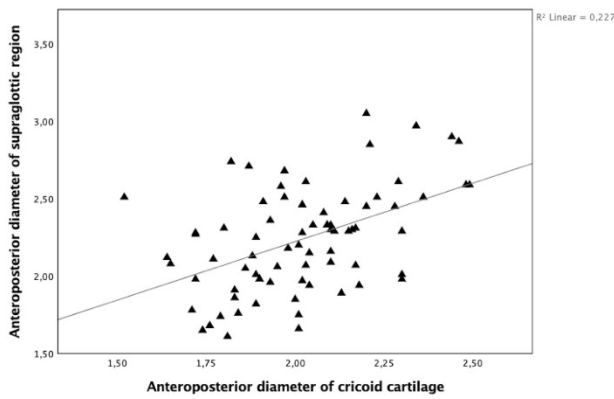


Figure 6. Correlation between anteroposterior diameters of the supraglottic region and the anteroposterior diameter of the cricoid cartilage in men

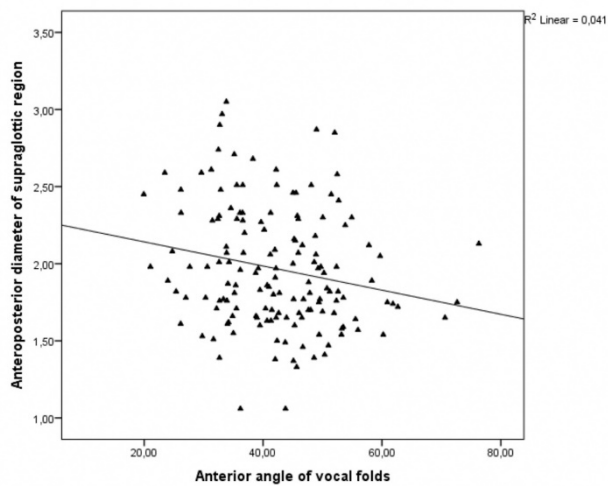


Figure 7. Correlation between anteroposterior diameter of the supraglottic region and anterior angle of the vocal folds in all patients

Discussion

This study evaluated the detailed morphometrical properties of the larynx in adult Turkish population using CT images. Our results indicated that the transverse diameter of the rima glottidis was the narrowest part of laryngeal passage while the patients rested in supine position. These findings suggest that the transverse diameter of the rima glottidis has clinical importance during endotracheal intubation procedure. Overall during intubation procedures this passage has a greater risk to damage.

Since the anatomy of the larynx undergoes multiple alterations till the puberty, most of the studies were focused on the morphometric properties of the larynx in pediatric populations. These studies reported that the narrowest part of the larynx was the subglottic region in pediatric patients (15-18).

Joshi M et al. (2011) completed a cadaveric study using 50 specimens to evaluate the gross anatomical properties of the cricoid cartilages in adult Indian population. According

to their results, the anteroposterior and transverse diameters of the cricoid cartilage were bigger than our results (2). Furthermore, other cadaveric studies reported that these diameters of the cricoid cartilage demonstrated differences among the various populations (19-21). The laryngeal skeletons that were used for the morphometric evaluations of the cricoid cartilage in the studies mentioned above, had been purified from the surrounding soft tissues. In our study, the measurements of the anteroposterior and transverse diameters of the cricoid cartilage were smaller in comparison to the findings of the hitherto studies. The differences between these studies may be related with the different method selections. Other study which was completed in the North Indian population, 60 individuals' CT images were studied to evaluate the laryngeal skeleton's diameters including the cricoid cartilage (22). Although their results were similar with our study, the population differences should be kept in mind before performing any laryngeal procedures such as intubation or surgery. Variations of the laryngeal skeleton are widely seen; therefore, individual radiological examinations, such as CT or MRI, are important to prevent unexpected injuries during intubation procedures (23).

Another CT study including 181 adult patients who had undergone general anesthesia for lung operations reported the diameters of the cricoid ring (5). Likewise, to our findings, their results indicated that the cricoid cartilage was larger in men. Although Shiqing et al. (2018) reported that the mean values of the transverse diameter of the cricoid cartilage were similar with our findings, the mean values of the anteroposterior diameter of the cricoid cartilage in their study were smaller than our results. These differences may occur since the patients in their study had undergone the general anesthesia. Since the general anesthesia causes relaxing all muscles, anatomical position of the rima glottidis may change, therefore, physicians should decide their intubation procedures with being aware of patients' anesthesia situation.

Seifpanahi et al. (2017) reported the changings of rima glottidis' positions after applying transcutaneous electrical stimulation. They compared the anterior angles of the vocal folds using a video laryngoscope in resting position and during electrical stimulation (24). The mean value of the anterior angle of the vocal folds during the resting phase was higher than our study. Using different methods or causing mucosal irritation during endoscopy could lead to inaccurate results. In contrast to their study, women had a wider anterior angle of vocal folds in resting position in our study.

Our results demonstrated that the anteroposterior diameter of the supraglottic region had strong effect on alterations in the cricoid cartilage morphometry ($R^2 = 0.44$). On the other hand, age had a weak role on the anteroposterior diameter of the cricoid cartilage ($R^2 = 0.043$).

The transverse and anteroposterior diameters of the cricoid cartilage were larger than the transverse diameter of the rima glottidis in our study. Although the rima glottidis could be abducted, soft tissue of the rima glottidis is under a great risk for injury during intubation.

Evaluating the trachea length was the one of the aims of present study. However, since the obtained CT images targeted the head and neck region in this study, evaluation of the trachea morphometry could not demonstrate trustable results. Its main reason was that the position of the patients should be set different than head and neck procedures, therefore, some artifacts could be seen during the present study.

In conclusion, larynx has a complex anatomy, therefore, managing laryngeal disorders requires a detailed knowledge about its morphometrical organization. The rima glottidis was the narrowest part of the laryngeal passage in our study, in contrast to the previous reports that mentioned the subglottic region had been the narrowest passage while endotracheal tube insertion. Since the cricoid cartilage has no expansion capability, subglottic part of the larynx is also important for selecting size of the endotracheal tube. However, selecting the endotracheal tube according to only subglottic part of the larynx may cause soft tissue injuries which may result with complications for voice production disorders such as dysphonia. Furthermore, our results indicated that the diameters of the cricoid cartilage were larger than the rima glottidis in all participants. This finding may be useful in the selection of an appropriate endotracheal tube for physicians working in the emergency units of hospitals by only applying indirect laryngoscopy. Thus, urgent cases, especially patients who suffer from respiratory disorders, could be intubated quickly, so the risks caused by oxygen insufficiency could be greatly reduced.

Limitation

The major limitation of this study is the absence of the patients' body mass index information such as height and weight, since this study was designed retrospectively.

Acknowledgments

Authors would like to thank for their Hospital's Radiology Department's staff for their support for presented study. There is no conflict of interest to declare. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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