European Archives of Oto-Rhino-Laryngology (2019) 276:2001–2005
https://doi.org/10.1007/s00405-019-05474-w

LARYNGOLOGY

Imaging of the age-related anatomical relationship between the innominate artery and the trachea

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Received: 14 February 2019 / Accepted: 14 May 2019 / Published online: 20 May 2019

Abstract

Purpose To measure the age-dependent changes of anatomical positions and relations between the trachea, cricoid cartilage (CC), and innominate artery (IA) in adults by computed tomography (CT).

Methods A retrospective cohort reviewing images of 127 consecutive adult patients who underwent CT angiography (CTA) of the neck. The trachea-to-IA (T–IA) distance was measured as the minimal horizontal distance between them. The vertical distance between the CC and the IA was measured between the axial section, demonstrating the CC's inferior border to the axial section at the level of the T-IA measurement.

Results Images of 125 patients (median age 53 years, range 18–89; 74 males) were reviewed. The mean T–IA distance was 2.3 ± 1.1 mm for males and 1.7 ± 0.9 mm for females ($P = 0.002$). The vertical C–IA distance was 44.2 ± 11.4 mm and 49.5 ± 12.5 mm for males and females, respectively ($P = 0.01$). Age correlated negatively with the vertical C–IA distance ($P < 0.0001$) and positively with the T–IA distance ($P < 0.0001$). The rate of IA variants was 23.2%, with no significant difference between the measurements of distances among patients with or without IA variants.

Conclusions This is the first description of the relationships between the trachea, CC, and IA distances in adults as depicted on CTA. The T–IA distance becomes larger while the T–CC distance becomes shorter with age.

Keywords Innominate artery · Tracheo-innominate fistula · Tracheostomy · Trachea

Introduction

The anatomical relationship between the trachea, the larynx and the innominate artery (IA) is important in surgical procedures involving the neck (e.g., retrosternal thyroidectomy, tracheal resection, tracheostomy, and others). For example, the evaluation of the neck prior to tracheostomy includes palpation of three anatomical landmarks: the cricoid cartilage (CC), the sternal notch, and the trachea. During that procedure, it is imperative to palpate and assess the course of the IA to avoid the devastating complication, though extremely rare, of intraoperative bleeding from the IA is [1–4]. In the postoperative course of a tracheostomy, it is essential to know the level and proximity of the IA to the trachea due to the risk of a trachea-innominate artery fistula (TIAF) formation, related to the use of cannula. The reported incidence of TIAF is between 6 and 0.8% [5, 6], with a survival rate of about 14% [7]. TIAF formation is thought to be attributed to both the anatomical relationship of the arterial trunk and the trachea, as well as to the damage of the inflated cuff or the tip of the tube itself to the tissue of the tracheal wall [8].

Oshinsky et al. [8] measured the position of the IA relative to the trachea in 10 cadavers and reported that the IA crosses anteriorly to the trachea between the level of the 6th and 10th tracheal rings. Fawcett et al. [9] described a mean distance of 6.57 mm between the IA and the trachea as depicted on computerized tomography (CT) in 71 patients up to 40 years of age.

The impact of age on the neck anatomy and physiology is important for surgical planning and outcomes. The goal of the current study was to measure the anatomical position and relations between the trachea, the CC, and the IA on CT

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studies. To the best of our knowledge, this is the first study to measure the proximity of the IA and the trachea in adult and elderly patients as depicted on CT evaluation.

Materials and methods

The imaging studies of 127 consecutive adult patients (median age 53 years) who underwent CT angiography (CTA) of the neck (standardized slices of 0.9-mm width) in the Sheba Medical Center emergency department were retrieved. These scans were performed as part of general evaluations for neurologic complaints or during evaluations in the emergency department. Two CT scanners were routinely used at the time of the study: Brilliance CT 64-channel scanner and iCT 256 CT scanner (Phillips, Cleveland, Ohio; manufactured in Haifa, Israel). Multi-planar reconstructions were used to realign the larynx on axial and sagittal planes. Excluded were the CTAs of patients with a positive history for laryngeal pathology, neck surgery, tracheostomy, previous radiotherapy to the cervical region and any IA pathologies. The CTA scans of inadequate technical quality as determined by a senior radiologist, and those of patients who had a nasogastric tube, an endotracheal tube, or a tracheostomy tube were excluded as well.

The trachea-to-IA (T–IA) distance was measured as the minimal horizontal distance between the adventitia of the IA to the adjacent tracheal ring (Fig. 1). The vertical distance between the cricoid cartilage (CC) and the IA was measured between the axial section that demonstrated the CC's anterior–inferior border to the axial section at the level of the T–IA measurement (Fig. 2). The angle between the trachea's anterior–posterior midline diameter and the point that was measured where the IA was closest to the trachea was determined, with the vertex of the angle being located on the center of the trachea's lumen (the midpoint of the trachea midline; Fig. 1). A positive angle indicated the IA was located to the right of the trachea midline and a negative angle indicated that it was located to the left of it. We also measured the T–IA and C–IA distances on a sagittal plane to verify our findings.

The measurements were reviewed by two senior (attending) otolaryngologists and a Student *t* test was performed to examine (and exclude) differences in the results. The study was approved by the Research Ethics Committee of the Chaim Sheba Medical Center, Tel-Hashomer, Israel (application number—5780-18-SMC).

Statistical analysis

The mean and standard deviations of each measurement were determined. The Student *t*-test was used to analyze the differences according to gender, age, and IA anatomy (with or without anatomical variants of the IA). Linear regressions were performed to analyze correlations between various measurements and patients' age.

Results

The neck CTA images of 127 patients (74 males and 51 females) were reviewed. Two male patients were excluded due to a history of neck surgery or radiation to the neck.

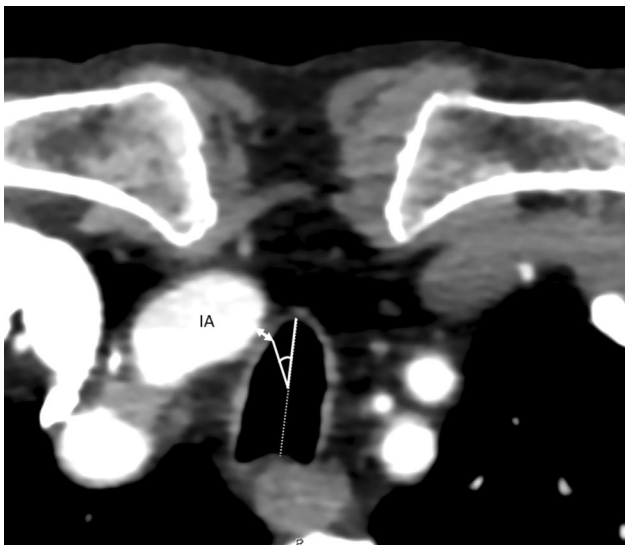

Fig. 1 An axial image demonstrating the distance between the trachea and the IA (double-arrow), trachea's midline (dashed line) and the angle between the trachea's center and the point closest to the IA. *IA* innominate artery

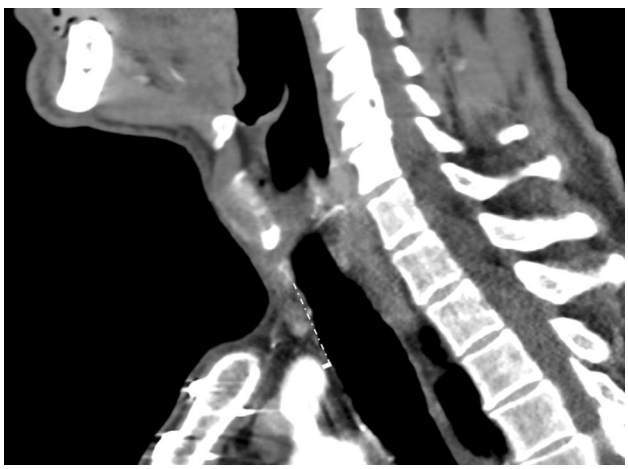

Fig. 2 A sagittal image demonstrating measurement of the distance (dashed line) between the inferior border of the cricoid and the level of the trachea that is closest to the IA (white thick line). *IA* innominate artery

The average ages of the 125 remaining study patients were 54.4 years for the males (range 18–89, median 56) and 49.7 years for the females (range 21–88, median 47).

The average T–IA distance, as measured on the axial plane, was 2.3 ± 1.1 mm (range 0–5.4 mm) among the males and 1.7 ± 0.9 mm (range 0–6 mm) among the females ($P = 0.002$; Table 1, Fig. 3). The respective vertical C–IA distances were 44.2 ± 11.4 mm and 49.5 ± 12.5 mm ($P = 0.01$). There was no difference between the results of the T–IA or C–IA distances when measurements on axial and sagittal planes were compared ($P = 0.49$ and 0.61, respectively). The minimum C–IA distance for the entire study population was 23.5 mm and the maximum distance was 77.4 mm.

The parameter of age had a significant effect on both the T–IA and C–IA distances. Regression models showed a significant negative correlation between the age of the entire cohort and the vertical C–IA distance ($P < 0.0001$; $R^2 = 0.22$), as well as a positive correlation to the T–IA distance ($P < 0.0001$; $R^2 = 0.18$). To demonstrate an effect of age on the various parameters, we divided the study population according to a median age of 53 years, yielding a "younger" (18–53 years, $n = 63$) and an "older" (54-89 years, $n = 62$) group. The T–IA distance was significantly shorter for the younger group compared to the "older" group (1.5 ± 0.7 mm vs. 2.6 ± 1.1 mm, respectively, $P < 0.0001$), and the C–IA distance was an average of 11 mm longer for the "younger" group (51.9 ± 11.3 mm vs. 40.7 ± 10.3 mm, respectively, $P < 0.0001$) (Table 1).

The CTA of 29 (23.2%) patients demonstrated IA anatomical variants [10]. A "bovine arch" IA was the most common among them ($n = 19$, 65.5%), followed by an "aberrant right subclavian artery" variant ($n = 5$, 17.2%) and an "isolated left vertebral artery" variant ($n = 3$; 10.3%). The rate of IA variants was similar among males and females (22.9% and 23.5%, respectively), and the mean age of this subgroup

Table 1 Innominate artery (IA) to trachea parameters

	By gender			By innominate artery variants (males and females)			By age (males and females)		
	Males ($n = 74$)	Females ($n = 51$)	P value	No IA variants ($n = 96$)	IA variants ($n = 29$)	P value	18–53 years ($n = 63$)	53–89 years ($n = 62$)	P value
Trachea to IA[a] (mm)	2.3 ± 1.1 (0–5.4)	1.7 ± 0.9 (0–6.0)	0.002	2.1 ± 1.1 (0–6.0)	1.9 ± 0.8 (1–4.0)	0.51	1.5 ± 0.7	2.6 ± 1.1	< 0.001
Cricoid to IA[b] (mm)	44.2 ± 11.4 (24.3–72.8)	49.5 ± 12.5 (23.5–77.4)	0.01	46.7 ± 11.7 (24.3–77.4)	45.0 ± 13.8 (23.5–72.8)	0.7	52.9 ± 11.3	40.7 ± 10.3	< 0.001
Angle between midline and IA[c] (degrees[d])	19 ± 22° [(− 44°)–79°]	9 ± 25° [(− 74°)–64°]	0.042	15 ± 23° [(− 74°)–64]	14 ± 26° [(− 35°)–79°]	0.76	14 ± 23°	40 ± 26°	< 0.001

[a]Minimum distance measured between the tracheal ring and the IA adventitia (Fig. 1)

[b]Minimum distance measured between the inferior border of the cricoid cartilage and the level where the IA is at the minimal distance to the trachea (Fig. 2)

[c]An angle measured between the midline of the trachea and the point where the IA is at the minimal distance to the trachea (the vertex of the angle is the center of the trachea) (Fig. 1)

[d]A positive degree means that the IA is to the right of the tracheal midline and a negative degree means that it is to its left

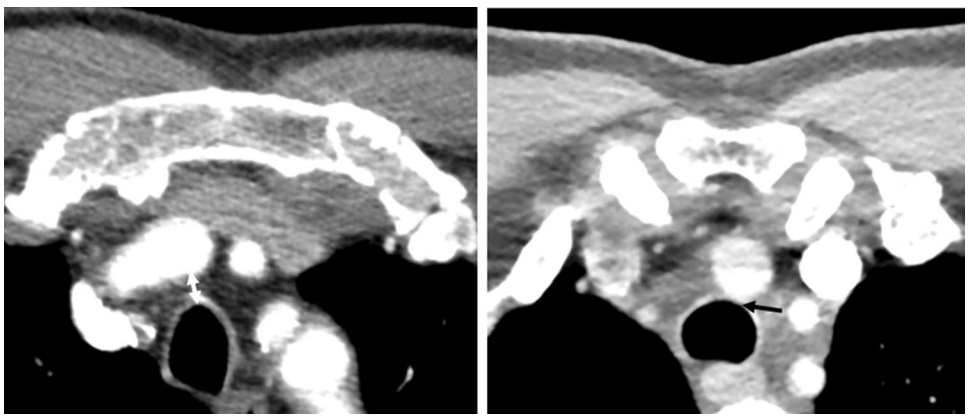

Fig. 3 Two axial images demonstrating the variability in the distance between the innominate artery and the trachea: 5.8 mm (white double arrow) vs. < 1 mm (black arrow)

was 51.4 years, which is similar to that of the entire study population (54.4 years). There was no significant difference between the measurements among patients with or without IA anatomical variants (Table 1).

Discussion

Knowledge of anatomical landmarks and relationships is essential during the preoperative, intraoperative, and postoperative evaluation of the neck. Many of the measurements available in the textbooks and the anatomical literature are based on small numbers of cadaveric dissections [8]. Furthermore, these structures change their position and relationship with growth and aging. Fawcett et al. [9] reported that the T–IA distance was most commonly less than 1 mm before the age of 3 years, whereas it became around 6.57 mm by the 3rd and 4th decades. Those authors suggested that this difference might be related to the gradual decrease in size and involution of the thymus gland with time. The availability of imaging and other technologies facilitating accurate measurements and reconstructions enables the conducting of studies on large numbers of patients of different ages and with better precision [11, 12].

The elderly population experiences changes in sagittal alignment of the spine due to loss of supporting capabilities of the intervertebral discs that places increased stress on the facet joints. These changes include decreased lumbar lordosis, increased thoracic kyphosis, and anterior advancement of the C7 plumb line [13, 14]. As a consequence, and also due to the relaxation of the suprahyoid muscles, the position of the larynx descends with age [15]. This is in line with our measurements: the distance between the trachea and the IA, the distance between the CC and the IA, and the angle between the trachea midline and the IA. As described by Fawcett et al. [9], our results of T–IA distance measurements also demonstrated that the gap between the trachea and the IA increases with age. In their study, however, the age of the patients did not exceed 40 years, whereas the median age of the patients in our study is 53 years (range 18–89). In addition, our results of the CC–IA distance (a mean of 4.42 mm in males and 4.95 mm in females) differ from the mean of 6.11 mm reported by Oshinsky et al. [8] since we measured the distance from the level of the inferior border of the CC, whereas those authors measured the distance from its superior border.

The clinical implications of our results are related to both formation and evaluation of TIAF. The length of the vertical segment of a commonly used tracheostomy tube (distal to the curve) is about 40 mm (i.e., Rusch, CrystalClear Plus Tracheostomy Tube size 7.0 mm (Teleflex, Malaysia), and has a total length of 70 mm with a vertical segment of 40.2 mm). When the tube is inserted between the 2nd and the 3rd tracheal rings, the cuff is expected to be located at a level where the IA is adjacent to the wall of the trachea and the formation of TIAF is attributed to the position and pressure of the cuff [8, 12, 16].Thus, during the evaluation of tracheostomy-tube related bleeding and while performing fiber-optic flexible endoscopy via the tube, the examiner should bear in mind that the IA and the trachea are most probably closest at a point proximal to the end of the tube and cannot be viewed.

In our study, we addressed the issue of the anatomical variants of an IA. The rate of brachiocephalic variants (23.2%) was similar to the values reported in the literature [10], with no significant difference between the group with variants and the group without them.

Age was the most significant parameter for all three anatomical measurements examined. Our results suggest that the distance between the trachea and the IA becomes larger, the distance between the CC and the IA becomes shorter, and the angle between the midline and the IA grows wider with aging. These novel findings should be borne in mind when initiating a tracheostomy procedure and when following-up adult patients.

Funding None.

Compliance with ethical standards

Conflict of interest There are no financial or personal conflicts of interest to declare.

Ethical approval The study was approved by the Sheba Medical Center Institutional Review Board. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Retrospective study without intervention, data was retrieved anonymously from medical charts with no identifying information. Informed consent was not required by the Medical Center Institutional Review Board.

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