

Anatomical variations of the extracranial internal carotid artery: prevalence, risk factors, and imaging insights from CT-angiography

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Abstract

Purpose

To determine the prevalence of different EICA variations in CT angiography (CTA) of the neck and its predisposing factors.

Methods

In this prospective study from 2021 to 2023 that was conducted in the radiology department of Shafa Hospital, Kerman, Iran, all patients who had undergone neck CTA were invited to participate in the study. Expert radiologists blindly examined each CTA image for the following: EICA variations—coiling, kinking, straight morphology, and tortuosity—and the distance between the internal carotid artery with the apex of the epiglottis and the C2 lower margin.

Results

Of the 106 patients, the mean age of the participants was 55.9 ± 16.9 years. 64.2% of the participants were men, and 35.8% were women. The frequency of EICA variations was equal to 70.27%. Tortuosity, kinking, and coiling variation were found in 61.79%, 4.24%, and 4.24% of arteries, respectively. Also, 54.7%, 1.8%, and 0.94% of the participants had bilateral tortuosity, kinking, and coiling separately. There was a significant relationship between the prevalence of EICA variations and female, age, and hypertension.

Conclusion

The frequency of EICA variations in arteries and patients was equal to 70.27% and 73.5%, respectively. Tortuosity variation was present in 131 (61.7%) arteries, which was the most common variation. Females, old age, and hypertension were risk factors for EICA variations. There was no significant relationship between diabetes, tinnitus, ICA to the apex of the epiglottis, and ICA to the C2 Lower Margin distance with the occurrence of EICA variations.

Introduction

The internal carotid artery (ICA) is an s-shaped artery originating at the upper surface of the thyroid cartilage from the common carotid artery on each side, running through the parapharyngeal space, and entering the external opening of the carotid canal in the temporal bone [1]. The extracranial part of ICA (EICA) usually moves upward in the parapharyngeal space towards the skull without any collateral separating artery on its way [2]. However, this is not always the exact course since multiple anatomical courses of EICA have been observed, investigated, and classified [3, 4].

These EICA radiographic anatomy variations that influence the ICA course and distance to vital landmarks were initially classified by Weibel and Fields in 1965 [5]. Thereafter, other authors have made various modifications, while mainly three types of EICA geometrical variations in its course have been considered: tortuosity, kinking, and coiling [6, 7]. Tortuosity is a C or S-shape elongation or undulation that occurs along the ICA; coiling is defined as an elongation following a severe S-shape curvature or circularization of the ICA; and angularization of the ICA is called kinking, which is further classified into mild, moderate, and severe based on the angle between the two kinked segments [5, 8].

Notably, the course and distance between the ICA and vital anatomical landmarks, including the distance between the ICA and the pharyngeal wall, are particularly critical [8, 9]. Tortuosity, kinking, and coiling are risk factors for reducing the distance between the ICA and the pharyngeal wall, increasing the complications during pharyngeal surgeries and interventional procedures—especially the risk of bleeding [9–11].

Nevertheless, these anatomical variations are usually asymptomatic and are diagnosed incidentally, while only a limited number of cases cause symptoms in the patients [12]. EICA tortuosity can cause a decrease in blood pressure, in which the severity of the blood pressure drop is directly associated with the severity of tortuosity, raising the potential for complications such as intimal ulceration, carotid artery dissection, cerebral ischemia, and vocal cord palsy by putting pressure on the jugular vein tortuosity [7, 13]. Aging with the mechanism of intramural elastin damage in the arterial wall can cause an increase in the coiling of EICA, which usually occurs bilaterally. Also, hypertension is significantly associated with an increase in the amount of coiling in EICA [14–16].

Several methods, such as contrast-enhanced computed tomography (CT) scans, CT-angiography (CTA), and magnetic resonance imaging (MRI), have been used to check the ICA over time, but today CTA and MRI are considered the main methods of studying this artery [17].

In this study, we intend to determine the frequency of different EICA variations in the CTA of the neck, considering the great importance of reducing the distance between the ICA and pharyngeal wall, especially in diagnostic procedures and surgeries, and the predisposing factors for its reduction in the southern population of Iran.

Material and method

Study population

In this prospective cross-sectional study that was conducted in the radiology department of Shafa Hospital, Kerman, Iran from January 2021 to March 2023, the inclusion criteria were all the people who were satisfied to participate in the study, and in their neck CT-angiogram image, opacification of their EICA was well done. The exclusion criteria of this study consist of the presence of motion artifacts or masses that cause displacement of blood vessels in the CT-angiogram and, finally, the patient's lack of consent to continue participating in the study.

Study Design

The study protocol was approved by the Research Ethics Committee of Kerman University of Medical Sciences, and written informed consent was obtained from each participant. All 106 participants had probable carotid stenosis and were enrolled in the vascular surgery department of Shafa Hospital, which referred them to the radiology department for CTA. A 64-slice scanner (Aquilion 64 MDCT scanner; Toshiba Medical Systems, Tochigi, Japan) was used to perform CTA. The investigated area included the entire neck, from the upper thorax to the base of the skull. Vascular access was done by a 20 G or 18 G needle in the cubital veins, where the volume of iodinated contrast agent was between 60–90 cc and the injection speed were 4–4.5 mL/s. Bolus contrast agent was injected with an automatic syringe.

We investigate the demographic features of patients, such as age, sex, and past medical history. To assess the variations of the EICA and its anatomical relationships in CTA, specific measurements and criteria were employed. Variations such as coiling, kinking, straight morphology, and tortuosity were evaluated qualitatively by visual inspection of the reconstructed images. Additionally, quantitative assessments were performed to determine the distance between the EICA and two anatomical landmarks: the apex of the epiglottis and the lower margin of the C2. These measurements were obtained using the axial or reconstructed sagittal images, with the distance defined as the shortest linear distance between the EICA and the specified anatomical reference point. These assessments were conducted blindly by an experienced radiologist to ensure the consistency and reliability of the measurements.

Based on statistical calculations of Type I and Type II error significance, 106 patients were selected as the minimum sample size. The likelihood of mistakenly rejecting a genuine null hypothesis was set at 5% for Type I errors, or false positives. The Type II error rate, or false negative rate, was 20%, indicating the likelihood of missing a true effect.

Statistical Analysis

Qualitative variables were reported as numbers (percentage), while quantitative variables were reported as mean values (standard deviation (SD)). Statistical analysis was performed using SPSS 24 software (IBM, Armonk, NY, USA). The odds ratio (OR) test was used for analytical statistics. For all analyses, $p < 0.05$ indicates a statistically significant difference.

Results

The results of the present study showed that the mean $\pm$ SD age of the participants in the present study was 55.9 ± 16.9 years. The youngest participant was 20 years old, and the oldest participant was 89 years old. 64.2% ($n = 68$) of the participants were men, and 35.8% ($n = 38$) were women. 45.2% ($n = 48$) of the participants had hypertension. 16.9% ($n = 18$) of the participants were diagnosed with diabetes, and 44.3% ($n = 47$) of the participants had tinnitus.

EICA variations

The results showed that the frequency of EICA variations was equal to 70.27%. In the evaluation of different variations of EICA, tortuosity variation was found in 61.79% (n = 131), coiling variation in 4.24% (n = 9), and kinking variation in 4.24% (n = 9) of the arteries. Also, 54.7% (n = 58) of the participants had bilateral tortuosity, 0.94% (n = 1) had bilateral coiling, and 1.8% (n = 2) had bilateral kinking (Table 1).

Table 1
The frequency of EICA variations among patients.

		Left variation, No. (%)				Total, No. (%)
		Coiling	Kinking	Straight	Tortuosity	
Right variation	Coiling	1 (0.94)	0	0	4 (3.77)	5 (4.72)
	Kinking	1 (0.94)	2 (1.89)	0	2 (1.89)	5 (4.72)
	Straight	1 (0.94)	0	28 (26.41)	0	29 (27.35)
	Tortuosity	1 (0.94)	2 (1.89)	6 (5.66)	58 (54.72)	67 (63.21)
Total		4 (3.77)	4 (3.77)	34 (32.08)	64 (60.38)	106

Distance between the ICA and the pharyngeal wall

The mean $\pm$ SD of distance between the ICA and pharyngeal wall at the level of the apex of the epiglottis were 16.1 ± 6.4 mm for the right side and 18.3 ± 7.2 mm for the left side, and the C2 lower margin on the right and left sides of the body were 17.9 ± 7.9 mm and 19.5 ± 7.1 mm, respectively. The ORs of the variables in the present study are given in Table 2.

Table 2
Multivariate analytical results related to possible risk factors for EICA variations.

Risk factors	OR (95% CI)	P
Age	1.1 (0.7–1.5)	0.01
Female	1.8 (1.1–2.5)	0.03
Hypertension	1.3 (1.1–1.5)	0.02
Diabetes	1.4 (1.3–1.5)	0.14
Tinnitus	1.2 (0.8–1.9)	0.73
Distance between the ICA and the apex of the epiglottis	1.1 (0.8–1.6)	0.54
Distance between the ICA and the C2 lower margin	1.3 (0.9–1.7)	0.95

ICA: internal carotid artery; OR (95% CI): odds ratio (95% confidence interval).

Discussion

In this study, we intend to determine the frequency of different EICA variations in the CTA of the neck, considering the great importance of reducing the distance between the ICA and pharyngeal wall, especially in diagnostic procedures and surgeries, and the predisposing factors for its reduction in the southern population of Iran.

The results of the present study showed that the frequency of EICA variations in arteries was equal to 70.27%, and there were tortuosity variations in 131 (60.6%) arteries, kinking variations in nine arteries (4.1%), and coiling variations in nine arteries (4.1%). EICA morphological variations were present in 78 (73.5%) patients; they were unilateral in seven patients (8.9%) and bilateral in 71 patients (91.1%). And among the patients in whom EICA had bilateral variations, 58 patients (81.6%) had bilateral tortuosity, two patients (2.8%) had bilateral kinking, and one patient (1.4%) had bilateral coiling.

The results of the study showed that tortuosity variation was present in 131 (61.7%) arteries, which was the most common variation in this study, which is in agreement with the results of three studies in the same direction [18–20].

In our study, there were coiling variations in 9 (4.24%) arteries and kinking variations in 9 (4.24%) arteries. Although there are various studies about coiling or kinking, there are still many unclear points about their etiology, clinical role, and best management method. One of the main causes of neck artery kinking is the decrease in the height of intervertebral discs due to aging [7]. Also, the results of various studies have shown that the prevalence of kinking in EICA in patients with hypertension has an increasing trend [21, 22]. The results of various studies have shown that variations in different parts of the ICA are also found in infants, which are caused by embryological reasons [1, 23].

The results showed that there was a significant statistical relationship between the frequency of EICA variations and females, which is in line with three studies [20, 24, 25]. Probably, the cause is due to the significant effect of hormonal changes on the vascular wall in women due to age [26]. Also, there was a significant association between the frequency of EICA variations and increasing age, which was consistent with other papers [20, 24, 27].

The results of our study showed that there was a significant statistical relationship between the frequency of EICA variations and the presence of hypertension, which was in line with the results of two other studies. According to the results of this research and other similar studies, hypertension can be considered one of the main risk factors for carotid artery variations [27, 28].

In this study, there was no statistically significant relationship between the distance of the ICA to the apex of the epiglottis ($p = 0.54$) and the distance of the ICA to the lower margin of the C2 ($p = 0.95$) and the OR of the occurrence of EICA variations. Alsini et al. (2017) showed in their research that the average distance of the ICA from the tonsils is 2.5 mm, and anomalies and variations of the ICA can cause severe arterial bleeding during neck and pharynx surgeries [29].

Ceylan et al. (2010) stated during research that in cases of variation and anomaly of the ICA, one should pay attention to the high risk of performing procedures such as tonsillectomy, adenotonsillectomy, and uvulopalatopharyngoplasty [30].

This current research had limitations such as a low sample size—due to restrictions related to the COVID-19 pandemic—and a limited time frame. Considering that this research was conducted for the first time in the southeast of Iran and the lack of similar research in the region, in order to more accurately compare the results of this research with other regional research, it is suggested that future supplementary research should be carried out with a larger sample size, in different geographical areas, and over a longer period of time so that the necessary preparations can be made to design a criterion for predicting anomalies. Carotid artery with sensitivity, specificity, positive predictive value, negative predictive value, and appropriate accuracy—based on the most common risk factors.

Conclusion

The results of the present study showed that the frequency of EICA variations in arteries was equal to 70.27% and that EICA morphological variations were present in 78 (73.5%) patients. Female sex, old age, and hypertension were important risk factors for EICA variations that must be taken into account. There was no statistically significant relationship between diabetes, tinnitus, the distance of ICA to the apex of the epiglottis, the distance of ICA to the C2 lower margin, and the OR of the occurrence of EICA variations.

Declarations

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Ethical Approval

Ethics Committee for Biomedical Research of Kerman University of Medical Sciences (IR.KMU.REC.1398.050).

Author Contribution

A Barfzadeh: Protocol/project development, Data collection or management, Manuscript writing/editing.

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