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Distance of the cervical part of the internal carotid artery from the selected anatomical structures in the parapharyngeal space and its relation to patient characteristics

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Anomalies of the internal carotid artery (ICA) can increase the risk of haemorrhage during common surgical procedures. The aim of this literature review was to summarize the current state of knowledge on the course of the internal carotid artery in the parapharyngeal space, including the impact of the patient characteristics on the distances between the artery and other anatomical structures, as well as symptoms accompanying the aberrations. Pathologies related to the course of ICA in the parapharyngeal space are common (10–60% in the general population and up to 84.4% in the elderly). In women, the distances in the oropharynx area are shorter than in men. Although the number of morphological studies is growing, providing more information on this topic, the identified studies differ in the methods and results. Knowledge on the variability in the course of ICA can help identify patients at high risk for the ICA trauma during pharyngeal procedures. (Folia Morphol 2024; 83, 2: 253–261)

Keywords: internal carotid artery, tonsillectomy, haemorrhage, arterial aberrations, pharyngeal procedures, arterial anomalies, arterial trauma

INTRODUCTION

According to Bochenek and Reicher [6], the internal carotid artery (ICA) begins at the level of the upper margin of the thyroid cartilage and ascends in the neck within the carotid sheath, turns 90° anteromedially within the carotid canal to run through the petrous part of the temporal bone. The cervical part of the artery is S-shaped and bends medially. When entering the parapharyngeal space, it crosses the stylohyoid muscle and the posterior belly of the digastric muscle. Studies on ICA reveal that its anomalies appear with the frequency that ranges from

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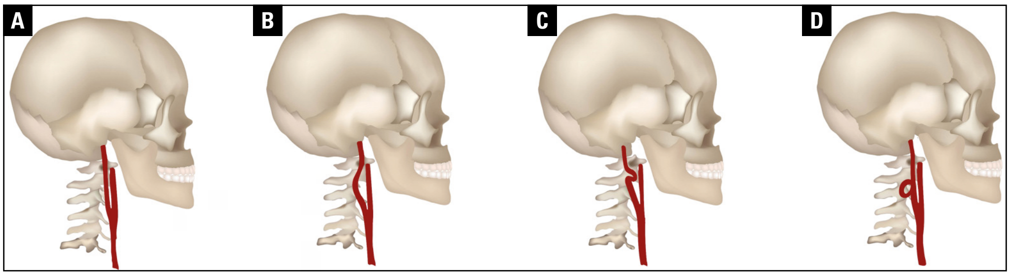

Figure 1. Most common course of internal carotid artery; **A.** Normal course; **B.** Curved course (tortuosity); **C.** Kinking; **D.** Coiling. Adapted from Paulsen et al. [31].

10% to 60%. They severely depend on a research method; however, not all abnormalities have clinical significance. Uncommon course and anomalies of ICA can cause problems after injuries or planned surgeries. Iatrogenic ICA injuries are associated with high rates of morbidity and mortality [16]. Complications include bleeding, thromboembolic events, carotid cavernous fistulas, and pseudoaneurysms; however, they can be also followed by persistent neurological complications [37].

The first internal carotid artery trauma during surgery was described by Pean in 1780 [32, 43]. A series of acute haemorrhages was also mentioned in the literature of the early XX century [43]. One of them describes a case of death following tonsillectomy: during this surgical procedure, the ICA coil, which had been bending medially just by the pharyngeal wall, was completely removed, causing a massive bleeding [12]. Post-tonsillectomy fatalities, according to different authors, can occur with a frequency from one per 3000 operations to one per 100,000 operations [36]. The mortality rate after tonsillectomy is low, but almost 30% of the deaths are due to bleeding after trauma, due to incision of ICA or external carotid artery and its branches [34]. Therefore, having the knowledge about the variability of ICA in the context of the patient characteristics (for example age, weight [9], gender [21, 42]) can be helpful in estimating the risk of arterial injury during tonsillectomy, and thus, reduce post-tonsillectomy mortality. Although many cases of abnormal arterial course were reported in the literature [1, 14, 20, 22, 29], only a few of them provided applicative and accurate information about topography of ICA [21, 25]. Increase of the knowledge on the possible course of ICA can help properly assess and qualify patients for surgical procedures. To address this topic, we conducted a literature review with the aim to summarize current knowledge on the course of the cervical part of the ICA in the parapharyngeal space, including the impact of the patient characteristics on the distances between the artery and other anatomical structures, as well as symptoms accompanying the aberrations.

MATERIALS AND METHODS

A review of literature included publication from the inception to 2022. The articles were searched in PubMed, CinicalKey, UpToDate and Scopus databases. Selected key words or their combination were used, including of MeSH terms and text word, such as internal carotid artery, anomaly, arterial trauma. Articles in English were considered. The review aimed to provide an up-to-date overview of the latest articles in the field; paper were selected based on our experience while focus of the review is placed on highlighting noteworthy issues of ICA anatomy which a clinically meaningful.

ICA ABERRATIONS AND DISTANCE FROM ANATOMICAL STRUCTURES

Aberrant ICA is a variant of the internal carotid artery that is characterised by altered course, structure or its absence [13]. The most common aberrations are related to the altered course of ICA which can include curved course, kinking and coiling (Fig. 1) [15, 31].

In the literature, there are two authors who attempted to classify the carotid artery aberrations according the criteria shown in Table 1.

Most of the times, aberrant ICA is diagnosed with imaging techniques which can provide various anatomical measurements including the distance from other anatomical structures. The results can differ widely depending on the research method, research group and imaging technique. When aberration of ICA remain undiagnosed, they can lead to accidental damage of this artery resulting in severe haemorrhages accompanying the tonsillectomy [20, 41] or adenoidectomy [7, 40], Eustachian tuboplas-

Table 1. Classifications of internal carotid artery aberrations, based on the selected studies

Author	Weibel and Fields, 1965 [39]	Paulsen et al., 2000 [31]
Grade 1 of aberration	Angle of artery bending is less than 30°	Straight course of the artery, without flexure, when the vertical deviation is lower than 15°
Grade 2 of aberration	Angle of artery bending is between 30° and 60°	Curved artery, with the vertical deviation between 15° and 70°
Grade 3 of aberration	Angle of artery bending is between 60° and 90°	Kinked artery, with the deviation greater than 90° but lower than 145°
Grade 4 of aberration	–	Coiled artery, when a loop of 360° can be noticed
Type of materials	Retrospective studies with angiogram	Human cadavers
Overall	That study refers mainly to the bend of the ICA and the elongation of the vessels	Division of aberration follows its direction — medial, lateral and dorsoventral deviations are distinguished

Table 2. Distance between the internal carotid artery and the tonsillar fossa

Source	Measurement value
Zuckerkandl [44]	2 cm
Myers [28]	2.5 cm posterolaterally
Bochenek and Reicher [6]	1–2 cm posteriorly
Jackson et al. [20]	1.9–2.55 cm posterolaterally

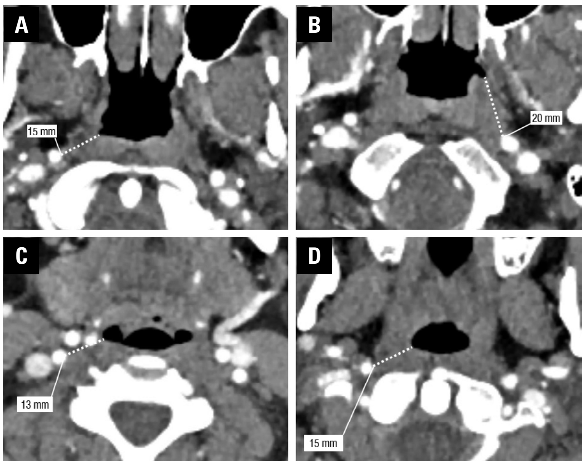

Figure 2. Measurements between internal carotid artery and clinically important distances in the parapharyngeal space using computed tomography angiography; **A.** Distance between internal carotid artery (ICA) and Rosenmuller Fossa (nasopharynx); **B.** Distance between ICA and visible part of the Eustachian tube opening (nasopharynx); **C.** The shortest distance between ICA and pharyngeal wall at the level of recessus piriformis (laryngopharynx); **D.** The shortest distance between ICA and pharyngeal wall at the level of oropharynx.

ty [19], peritonsillar abscess drainage or the soft palatoplasty [33]. For this reason, knowledge of the clinically important distance between ICA and selected anatomical structures is essential for any surgical procedure performed in the pharyngeal area. For tonsillectomy, the measurement taken between the artery and the tonsillar fossa is of greatest importance. Some authors mention the physiological values of this distance, as seen in Table 2. Certain types of ICA aberrations can cause a significant change in distance and increase the threat of perioperative complications. Pre-operative radiological examinations, computed tomography angiography in particular, can exactly show the clinically important distances, detect artery anomalies and reduce perioperative risks (Fig. 2).

There is only one scale of relevant surgical risk, described by Pfeiffer and Ridder and based on the two parameters, the level of anomaly and the carotid-pharyngeal distance [9, 32]. The scale ranges from grade 1 (low surgical risk — the distance of at least 10 mm between ICA and the pharyngeal wall, at the levels of the nasopharynx and oropharynx) to grade 4 (high surgical risk — ICAs at the same level but 2 mm closer to the pharyngeal wall). Pfeiffer and Ridder also reported that surgical access, in the nasopharynx and oropharynx is relatively limited in comparison to the level of hypopharynx [32]. Furthermore, tonsillectomy, like the other surgical procedures at these levels, is often performed in children, where the distances mentioned above are shorter. In addition, no visual control or image guidance is usually used, what significantly increases the risk of ICA injury [32, 43]. The Pfeiffer's research group was based on 35 course anomalies of the ICAs in 21 patients in the age between 2 and 82 years, with different clinical diagnoses. In the comparison to the data from other studies, such a number of research subjects is relatively small to form any relevant conclusions and happens to be a justified statement [3, 20, 23, 32, 36, 38, 39, 43].

The impact of ICA aberrations on the course of the artery in the pharyngeal space have been well described. According to the literature, aberrations of the

Table 3. Factors inducing the internal carotid artery (ICA) anomalies

Cause	Description
Congenital	No difference in frequency of anomalies between age groups [3, 43], usually occur bilaterally.
Ageing	Degenerative changes (the loss of connective tissue) induce the aberrations; Cervical part of the ICA is a vessel of the elastic type (on the contrary to the fibrous cranial part) what makes it susceptible to distortion [8, 18]; Reported more often in elderly age groups [3, 11, 18].
Regressive evolutionary change	In reference to the Fleming's comparative anatomy, certain species have significantly longer artery than neck, which results in arterial tortuosity [43].

ICA significantly reduce the mean distance between the artery and the pharyngeal wall. There are three main factors that tend to induce the appearance of ICA anomalies, as reported by various authors (Table 3) [1, 8, 9, 29, 31, 32, 39].

Noteworthy is the fact, that on the other hand some authors claim that the severity (kinking and coiling) of the cervical segment of ICA did not shorten the mean distances from the artery to the nasopharyngeal walls. Besides, there was only a little difference (less than 2 mm) between minimal distances in each aberrant and straight artery at the level of nasopharynx. The authors conclude that this minimal measurement is an extreme value, in association with other factors, such as age, sex and weight [3, 25].

ICA ABERRATIONS AND PATIENTS' CHARACTERISTICS

Deutsch et al. [9] investigated the distance between ICA and tonsillar fossa in children. As a result, they reported an increase in this distance with age and weight, obtaining the values typical for an adult at the age of 12 years or weight of 56 kg. Aberrations of the ICA are believed to be rare in children and young adults [43].

Jun et al. [21] discovered that in the nasopharynx, oropharynx and hypopharynx, the distances are relevantly shorter in women ($p < 0.01$), what is consistent with the Togay-Isikay's results [24, 38]. The results are probably connected with the different relations in men and woman between the body and neck size [24]. Furthermore, the decreased thickness of soft-tissue and muscle layers in females is probably the causative factor of more frequent appearance of ICA anomalies in this group [21]. The Zając's study [42] also states that ICA is closer to the parapharyngeal wall in women then in men but only at the Eustachian tube opening level in nasopharynx. Furthermore, Jun et al. [21] found that in nasopharynx and oropharynx, the distance was inversely proportional to the age ($p = 0.00$). No correlation was found for the hypopharynx level. Moreover, the increasing number of anomalies in adults is believed to be a cause of shortening of the carotid-pharyngeal distance.

Taking under consideration the clinical value of the course of the ICA, a lot of research can be found on post-tonsillectomy haemorrhage [17, 35]. A study conducted by Riechelmann et al. [35] in 2011–2012 revealed that postoperative haemorrhage occurred in 55 cases of the 300 tonsillectomies performed. There is no detailed information whether the cause of the injury was the ICA trauma. Post-tonsillectomy bleeding was more frequent in adults than in children. Haemorrhage was observed in 18.9% of normal-weight patients, 11.1% of underweight patients and 18.7% of overweight patients ($p = 0.7$). Data distribution (based on age and weight) did not influence bleeding risk ($p = 0.8$). In total, 3.7% of the patients had to be operated on again due to the injury, but there is no detailed information on whether it was caused by ICA trauma [35].

ACQUIRED AND CONGENITAL DISORDERS AFFECTING ICA COURSE

Elastic fibres and muscular tissue has been demonstrated to be substituted by the loose connective tissue, which leads to metaplasia of tunica media of ICA. It is hypothesized, that the extracranial ICA, as a transition zone between an elastic vessel (common carotid artery, CCA) and a muscular vessel (intracranial ICA), is particularly subject to metaplastic transformation. This can result in numerous aberrations. Destruction of the vessel wall causes its elongation and susceptibility to bending stress during systole. It is a direct cause of the development of an arterial kink. Unquestionably, vessels are also more prone to deformations under high blood pressure [43].

One of the common statements in the literature is that coiling is due to embryological causes, while tortuosity and kinking are triggered by atherosclerosis and fibromuscular dysplasia. On the contrary, Beigelman et al. [3], in a group of 885 patients (1–90 years), did not show differences in the prevalence of kinking or coiling among age groups, favouring the embryogenic mechanism of all types of the anomaly development. Macchi et al. [26] reported that carotid kinking was present in 38% of cases without atherosclerosis, diabetes or hypertension. On the other hand, Del Corso et al. [8] claim that ICA anomalies were found in over half of the patients with cardiovascular diseases and transient ischaemic attacks [21, 25]. Other studies of carotid kinking showed a prevalence of 5% to 25% in patients with cerebrovascular symptoms or incidentally diagnosed asymptomatic carotid stenosis [20]. Another study by Togay-Isikay et al. [38] reported that according to ultrasonographic examinations carried on in 345 patients, ICA anomalies were not caused by vascular risk factors or atherosclerotic lesions of the vessels. Moreover, the authors claim that it should not be connected with a history of the cerebral or cardiac ischaemic symptoms or a presence of the ICA stenosis.

Other pathologies such as inflammation processes or hypertension have also been taken into account. Wraige et al. [41] formed a statement that chronic infections of the tonsils can increase the risk of the ICA incision during tonsillectomy due to local spasm or thrombosis. Pancera et al. [30] reported that ICA anomalies occur significantly more often in hypertensive people than in normotensive. They concluded that ICA aberrations have a minor impact on the creation of atheromatic plaques. According to Benes et al. [4], only one type of arterial kinking is formed in adults on the basis of a plaque, whereas the other are congenital and appear mostly in women. Arterial kinking in older age is considered to be an acquired lesion, most common in patients with arteriosclerosis and hypertension. In children and younger patients, the kinks and coils are congenital. Furthermore, in this group, the important impact can have congenitally-originating disorders like Loeys-Dietz Syndrome, Marfan syndrome or artery tortuosity syndrome.

SYMPTOMS

ICA, located directly underneath the mucosa of the pharyngeal wall, can be palpable and sometimes even visible on the physical examination. Parapharyngeal ICA aberrations are asymptomatic in 80% of cases [32]. In many cases, aberrant course of ICA is asymptomatic. Muñoz et al. [27] who reviewed 5,500 CT scans identified 14 adult patients whose cervical portion of one or both ICAs meet criteria of having aberration. Ten of 14 patients (71%) were asymptomatic. The remaining patients complained about pulsatile masses, longstanding hoarseness, foreign body sensation, and upper respiratory distress.

Variations in arterial course are usually revealed by the physical and radiological examination or even during the surgery. The symptoms occur more often in older people — a common theory is that ageing exacerbates the embryological pathology of the ICA course [11, 18, 31, 32, 43]. The most frequently reported symptoms occurring in relation to parapharyngeal ICA aberrations are difficulties with speech, dysphagia, pharyngeal pressure or sensations of a foreign body presence, intraoral perception of noise or vascular pulsations [32]. Untypical manifestations such as dizziness, tinnitus, cephalgia, cervical dysesthesia, cervical pain and glossopharyngeal neuralgia can often be ignored by patients, and therefore the pathology may remain unrecognized. Only 4% to 20% of the ICA anomalies are directly related to cerebrovascular insufficiency [23].

Galletti et al. [14] described five cases of ICA seen as a pulsing mass on physical examination. In four of the patients, it was asymptomatic but in the case of an eight-year-old child, complaints of dysphagia and pain in the pharynx were reported. It is noteworthy that the patient was suffering from the recurrent tonsillitis. Among the 21 patients examined by Pfeiffer and Ridder [32], there were only two with dysphagia and sensation of a foreign body presence.

ICA ANOMALIES AND TYPES OF IMAGING TECHNIQUES

The research of the extracranial ICA course strongly differ in results, due to methods of imaging technique used (Table 4). Galletti et al. [14] pointed out that time-of-flight magnetic resonance angiography is the best imaging technique to confirm the diagnosis of the ICA aberration. However, Ekici et al. [11] reported that multi-detector computed tomography (MDCT) angiography is a more appropriate method. Taking the literature into consideration, only two studies based on the MDCT were to be found [11, 21]. The results of MDCT use are usually similar to ultrasound techniques, but the number of detected ICA anomalies is significantly larger than by using traditional computed tomography. The authors explain that the cause lies beneath the greater accuracy of the new imaging methods.

There are seven studies in the literature on the measurements of the clinically important distances between the cervical part of ICA and anatomical structures. In 1995, Deutsch et al. [9] correlated the distance between ICA and torus tubarius with age and sex in children. This was the first study that reported an increase of this distance with age and weight, obtaining the values typical for an adult at the age of 12 or a weight of 56 kg. In 2012, Ekici et al. [11] published work on differences in the distances at different pharynx levels. In the oropharynx, the artery was located closer to the pharyngeal wall than in the nasopharynx. It turned out that considering the measurement to torus tubarius as a factor determining the threat of injury during tonsillectomy is quite controversial. Pfeiffer and Ridder [32] and Jun et al. [21] were in line with Ekici et al. [11]. Nevertheless some authors acknowledge torus tubarius as a credible point of reference in surgical procedures performed at the oropharynx level despite the fact that this particular structure is located in the nasopharynx. As shown in Table 5, anatomical distances, itself and correlated with age, sex and weight, differ depending on research methods and imaging techniques.

Furthermore, there are numerous suggestions about carrying out the radiological diagnosis prior to the surgery in parapharyngeal space, especially in a certain group of patients [11, 21, 38]. That indications are strongly supported by the scientific results: In patients over the sixth decade of life the anomalies occur with the frequency from 66.2% [21] up to even 84.4% [11]. The current knowledge about the course of ICA in the parapharyngeal space would be helpful in practice. For example, introducing the additional examination in the patients groups of frequent artery anomalies occurrence is reasonable. The knowledge about artery anomalies can be useful in reducing the risk in pharyngeal procedures.

Table 4. Frequency of internal carotid artery anomalies by selected research method

Method	Anomalies — frequency [%]
Dissection of human cadavers [2, 10, 11, 43]	20–40
Angiography (CT, MR) [23, 38, 39]	10–56
Doppler ultrasonography [8, 26, 31, 38]	24.6–58
MDCT angiography [11, 21]	58.8–60.3

CT — computed tomography; MDCT — multi-detector computed tomography, MR — magnetic resonance.

Table 5. Studies on internal carotid artery and clinically important distances in the parapharyngeal space

Author, year	Material and method	Selected results
Deutsch et al., 1995 [9]	100 children with a mean aga of 6 years (range 7–18 years) Retrospective study, MR	Distance between torus tubarius and ICA increases in the regular trend in children, reaching 25 mm with the age of 12 years or 56 kg of weight. The authors claim that the torus tubarius corresponds to the lateral extent of the tonsillar fossa and thus can be taken as the practical measurement point.
Pfeiffer and Ridder, 2008 [32]	21 patients and 35 AAs Retrospective study, CT angiography, MR angiography and Doppler ultrasonography	The mean minimum distances **between the pharyngeal wall and AAs had a value of 7 mm.** The minimal distances occurred more often in the **nasopharynx and oropharynx** than at the hypopharynx level.
Bergin et al., 2010 [5]	397 arteries, 200 patients (36% of AAs) Retrospective study; cervical CT scanning.	• Distance between torus tubarius and ICA average 23.5 mm, NAA: 23.8 mm; AA: 22.5 mm That distances decrease with the **age** of patients and are significantly shorter in **female.** • Distance between Rosenmuller fossa and ICA was very small in case of some patients (minimum value of 0.2 mm). Patients with aberrant ICA have significantly shorter than distance between torus tubarius and ICA (95% CI 0.4 Y 2.2 mm, p = 0.004).
Ekici et al., 2012 [11]	1214 arteries including 732 AAs MDCT angiography	• Mean minD: all arteries**: 11.13 mm** NAA: 13.00 mm; AA: 9.49 mm

AA — aberrant nasopharyngeal internal carotid artery; CI — confidence interval; CT — computed tomography; ICA — internal carotid artery; MDCT — internal carotid artery; MR — magnetic resonance; NAA — non-aberrant nasopharyngeal internal carotid artery.

Table 5. Studies on internal carotid artery and clinically important distances in the parapharyngeal space

Author, year	Material and method	Selected results
Jun et al., 2012 [21]	509 arteries (58.8% AA) Adult health routine examination, MDCT angiography	• Distance between pharyngeal wall and ICA largest at nasopharynx (15.8 ± 4.6 mm) decreased at oropharynx (15.8 ± 4.6 mm), shortest at hypopharynx (13.5 ± 6.0 mm). This distance is significantly **shorter in women** compared with men at **all** the three pharyngeal levels. Patients aged ≥ 60 years have aberrations more often (66.2% frequency). The distance in aberrant artery is shorter than in an artery without anomalies.
Lien et al., 2013 [25]	117 NNA, 39 AA MR brain scans MR angiograms	• Distance between torus tubarius and ICA NAA: 23.1 mm (min. 14 mm); AA: 19.7 mm (min. 13 mm) • Distance between Rosenmuller fossa and ICA NAA: 19.8 mm (min 11 mm); AA: 15.7 mm (min 9 mm) • Distance between posteriori pharyngeal wall and ICA NNA: 20.7 mm (min 15 mm); AA: 16.8 mm (min 12 mm) The mean distance between the artery and torus tubarius differs with the results of Bergin et al. [44]. The author claims that it is related with the diverse groups of patients (New Zealand Caucasians and Taiwan Han Chinese).
Zając et al., 2019 [42]	97 patients CT angiography	• Distance between ICA and Eustachian tube opening: all arteries: 19.8 mm (min. 9.7 mm). • Distances between ICA and pharyngeal wall at the level of epiglottis apex: all arteries: 16.5 mm (min. 2.5 mm).

AA — aberrant nasopharyngeal internal carotid artery; CT — computed tomography; ICA — internal carotid artery; MDCT — multi-detector computed tomography; MR — magnetic resonance; NNA — non-aberrant nasopharyngeal internal carotid artery.

CONCLUSIONS

Pathologies related to the course of ICA in the parapharyngeal space are common ranging from 10% to 60% in the general population and reaching almost 85% in elderly. Distances between the artery and other anatomical structures differ between men and women in whom they are shorter. People with ICA anomalies are at increased risk of bleeding during common surgical procedures, for this reason knowledge on the variability in the course of ICA can help identify patients at risk for the ICA trauma during the pharyngeal procedures. Although the number of morphological studies is growing, the overall knowledge on ICA anomalies and their impact on clinical procedures is insufficient. Further research is recommended.

Conflict of interest: None declared.

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