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AGENESIS OF THE INTERNAL CAROTID ARTERY - COLLATERAL VASCULARIZATION AND SYMPTOMATIC MANIFESTATIONS

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ABSTRACT

Introduction and objective: Internal carotid artery agenesis is a rare anatomical anomaly involving the absence of the internal carotid artery. It is a congenital developmental defect that can present with varying symptoms depending on whether it is unilateral or bilateral. The aim of this article is to summarize the diversity and prevalence of symptoms associated with unilateral or bilateral agenesis of the internal carotid artery.
Methodology: In the literature review, scientific works related to internal carotid artery agenesis were utilized, including 26 studies addressing the described variability, which collectively encompass 52 cases of patients with internal carotid artery agenesis. After a thorough analysis of the cited literature, conclusions were drawn regarding the frequency and relationships between unilateral and bilateral absence of the ICA.
Discussion: Agenesis of the internal carotid artery is a rare anomaly; however, its detection is crucial in the diagnosis of cerebrovascular disorders. Among symptomatic patients with internal carotid artery agenesis, intracranial aneurysms leading to subarachnoid hemorrhages were frequently observed. Additionally, collateral pathways replacing its blood flow, such as perineural anastomoses, and alterations in the normal course of other vessels in the neck and head region were also noted.
Conclusions: Agenesis of the ICA occurs in 0.01% of cases and is additionally associated with the absence of the carotid canal, through which the artery typically traverses. It is more commonly seen as left-sided agenesis of the ICA, with bilateral agenesis occurring in less than 10% of cases. 25% of cases of internal carotid artery agenesis are associated with intracranial aneurysms. The majority of symptomatic patients are between 35 and 65 years of age. Patients with internal carotid artery agenesis most frequently exhibit neurological disorders as well as nonspecific symptoms such as headaches and nausea.

KEYWORDS

Internal Carotid Artery, Neurology, Aneurysm, Anatomy

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Introduction

Fig.1. *Overview drawing of the main branches of ICA*

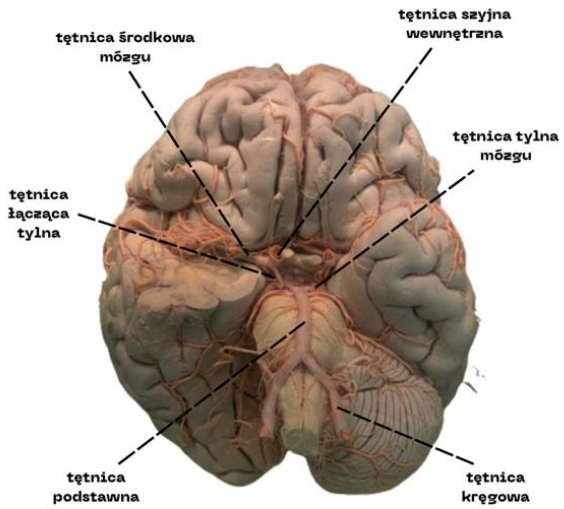

Fig.2. *Sectional material from the Department of Human Anatomy at the University of Medical Sciences in Lublin*

Internal carotid artery (ICA) is one of the two branches of the common carotid artery. It constitutes an important part of the cerebral vasculature. The ICA supplies blood to the anterior part of the brain, the dura mater, the ocular system, orbital structures, the forehead, and the nasal mucosa along with the paranasal sinuses. The internal carotid artery is a component of the cerebral arterial circle [1]. Agenesis of the ICA is a rare anomaly of this artery's position. It is a congenital developmental defect that often remains asymptomatic until the fourth or fifth decade of life. It is estimated that the frequency of this condition is 0.01%. The first case of this anomaly was discovered postmortem [2,3]. Symptomatic cases of ICA agenesis present with nonspecific symptoms: headaches and dizziness, nausea, and vomiting.

Considering the embryonic origin of ICA agenesis, the anatomical structure of a patient affected by this condition will differ significantly from a patient with a physiological course of the artery. Individuals without the ICA develop collateral circulation to compensate for the lack of flow, which often results in the absence of symptoms, unlike patients in whom the blood flow through the existing internal carotid artery has been suddenly restricted, causing acute stroke-like symptoms.

The purpose of this paper is to summarize the diversity and frequency of incidences with symptomatic unilateral or bilateral agenesis of the internal carotid artery.

Methodology

In this review, articles searched in PubMed were used. Publications were searched under the following terms: "internal carotid artery agenesis," "internal carotid artery abnormalities," "internal carotid artery absence," and "internal carotid artery aneurysm." A secondary search was also performed by reviewing the references of each previously read article. Papers from 1999-2023 were included in the review. The large time span results from the small number of available articles that were directly related to the research topic. Original works, reviews, and case reports were taken into account.

Ultimately, the review included 26 articles which described 52 cases of patients with agenesis of the internal carotid artery. The review compared age, sex, and symptoms in patients diagnosed with agenesis of the internal carotid artery and its canal in the temporal bone. The anomaly was visualized using imaging tests such as X-ray, CT, MRI, and untrasound.

Discussion

In "Bergman's comprehensive encyclopedia of human anatomic variation" it says that agenesis of the internal carotid artery occurs in 0,01% of cases and is associated with lack of the carotid canal, in which the artery physiologicaly runs. [1,3]. Left-sided ICA atrophy is more common and bilateral atrophy is present in <10% of cases. 25% of ICA agenesis cases are associated with intracranial aneurysms [3]. Online books, abstracts and original articles from 2020-2021 describe 466 cases of unilateral (398) and bilateral (68) agenesis of the internal carotid arthery (ICA). Within the 398 cases of unilatheral aplasia of ICA, 95 of them were connected to aneurysms. The calculated ratio of unilater to bilateral ICA agenesis is 5,8:1. The ratio of number of unilateral ICA aplasia to cases associated with aneurysms is 4,2:1 [4]. Agenesis of ICA occurs in connection to intrauteral mechanical or hemodynamic stres happening during the germinal/embryonal formation of the artery [5,6]. The primary internal carotid artery develops by the 4^{th} week of fetal life. However the base of the skull, which houses the canal for thi sartery does not form until the 5^{th} to 6^{th} week. Therefore, it is crutial in the diagnosis of ICA agenesis to confirm the absence of the carotid canal using computed tomography [7]. As a result of agenesis, various intracranial collateral pathways develop to compensate for the absence of the vesseles supplying the brain on one side. The formation of these pathways depends on the moment of the disruption in embryogenesis. If it occurs before emergence of the Circe of Willis, "primitive" collateral path such as the intercavernous anastomosis are most likely to develop. However, if the arterial circle is already present before the anomaly arises, compensatory callateral arteries form to make up for the absence of the ICA [5].

According to the available literature, variants of internal carotid artery agenesis have been identified and classified into types A-F (Lie's classification):

Type A and B: Described as an incomplete Circle of Willis.

Type C: Represents bilateral agenesis of the internal carotid arteries.

Type D: Involves the anastomosis of the cavernous segments of the internal carotid arteries.

Type E: Involves bilateral hypoplasia of the internal carotid arteries.

Type F: Involves the "rete mirabile" - a network of vessels connecting the external carotid artery with a short internal carotid artery within the skull [6,7]..

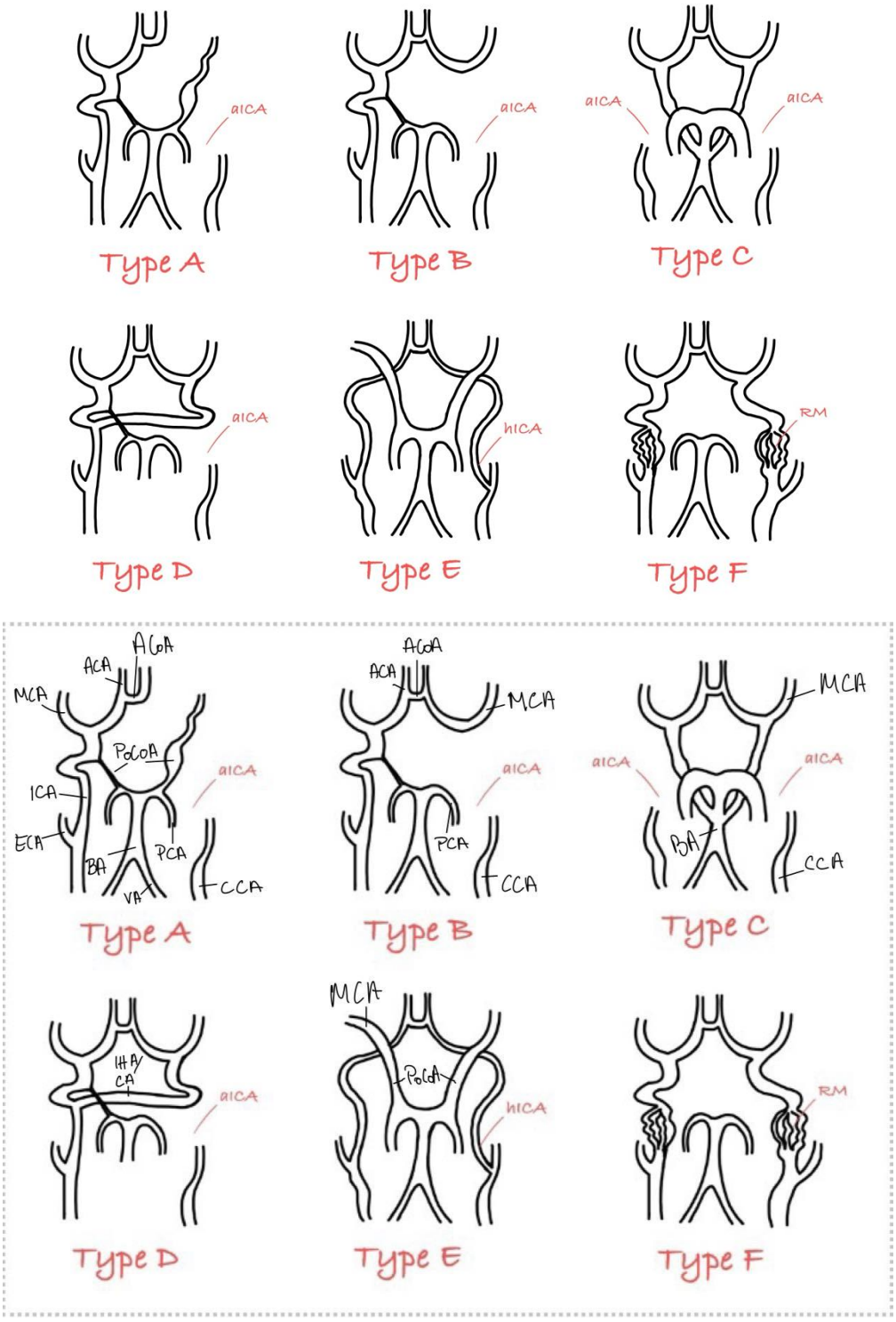

Fig.3 rysunek poglądowy klasyfikacji Liego [8]

ACA – anterior cerebral artery
ACoA – anterior communicating artery
MCA – middle cerebral artery
PCA – posterior cerebral artery
PoCoA – posterior communicating artery
BA – basal artery
VA – vertebral artery

ECA – external carotid artery
ICA – internal carotid artery
aICA – nabsent internal carotid artery
hICA – hypoplastic internal carotid artery
RM – rete mirable
IHA – inferior hypophysial artery
CA - capsular artery/ clival artery

Because ICA agenesis is not a hereditary condition it can involve patients of different genders and manifest itself at different ages. It is observed that most patients with symptoms are aged 35-65 [X]. From cases mentioned in the tables [Tab.1 and 2] we can observe that the average age of patients diagnosed is 41 years old, with a large discrepancy: 5-83. The gender distribution is equal: 25 men, 26 women an 1 person unspecified.

In patients, most observed symptoms are of neurological origin or non-specific like headaches or nausea. What is more, in the age group 36-65 there is a greater frequency of otolaryngological symptoms such as dizziness, problems with balance of tinnitus in comparison to other age groups. Additionaly, in compiled papers there were no cases of otolaryngological symptoms in patients younger than 36. Neuro-ophthalmological symptoms (visual disturbances, eye pain) appear with a similar prevalence but throughout all age groups. In the cited cases, these were attributed to a decrease in intraocular pressure or an embolism in the arteries, directly associated with the absence of the ICA [10]. There is also a possibility of psychiatric disorders accuring, such as memory impairement. There may be caused by a slowed blood flow to the brain due to the presence of aneurysms [11].

Over the years, various cases of detecting this anamaly have been documented. One such case is a 38 year old man who was admitted to the hospital following an accident. Angiography of the right external carotid artery revealed an anastomosis with a distal intracranial vessel via the internal maxillary artery but the intracranial vessels were poorly visible. Angiography of the right ascending pharyngeal artery showed an abnormal course and anastomoses with intracranial vessels. The proper internal carotid artery was absent. Angiography of the left external carotid artery detected a network of tortuous arteries connecting with the cavernous and petrous segments of the ICA. Both vertebral artery angiographies showed a sudden reduction in caliber at the level of the vertebrobasilar junction. Abnormal arterial collateral circulation originating from muscular-spinal branches and meningeal arteries was also described. Additionally, the basilar artery (BA) was absent. This is the first reported case of cranial rete mirabile (CRM) associated with bilateral segmental absence of the ICA and BA. The cause may be an abnormal development of the vascular connective tissue or extracellular matrix [12].

Another type of a rare vascular variation can be agenesis of the ICA with intercarvenous anastomosis. Although it must be differenciated from secondary causes of ICA stenosis and occlusion by providing a CT scan of an absent carotid canal. This variation was described in a case of a 58 yesr old man with a history of myocardial infarct and diabetes, who experienced sidden speech difficulties, numbness of the left side of the face and weakness of lef upper and lower limb. Neurological examination revealed dysarthria, left-sided facial paralysis, left hemiparesis and bilateral absence of plantar reflexes. Diffusion MRI revealed an infarct of the right middle cereblram artery (MCA). In the magnetic resonance angiography of the skull and neck left ICA was not visible distally to the bifurcation; left MCA was provided with blood via an intercavernous anastomosis between the right and left ICAs. Cranial CT showed the absence of the left carotid canal. Digital subtracion angiography allowed to confirm the agenesis of the left ICA with an intercavernous anastomosis [2].

Agenesis of the left common carotid artery with independent origin of the external and internal carotid arteries from the aortic arch is a well-documented but extremely rare congenital defect.

Agenesis of the left common carotid artery, with independent origin of the external and internal carotid arteries from the aortic arch, is a well-documented but extremely rare congenital defect. A case of this anomaly was identified in a patient with ankylosing spondylitis, as demonstrated by CT angiography and MRI. Recognizing this anatomical variant, especially before interventional procedures, is crucial as it can complicate catheterization of these arteries [13].

Right aortic arch and agenesis of the internal carotid artery are extremely rare vascular developmental defects. The etiology of both anomalies may be associated with abnormal regression of the dorsal aorta.

Absent ICA in notably associated – 24-67% - with intracranial aneurysms and an early detection can prevent serious complications for the patient, as in the case of a 28 year old male who experienced a singular episode of arterial hypertension. He underwent duplex ultrasound, which showed a diffused narrowing of the left common carotid artery (CCA) with a significant decrease in peak systolic velocity and suspicion of absent left internal carotid artery (ICA). Contrast-enhanced CT showed no abnormalities such as stroke or intracranial

vascular malformations but it confirmed a right aortic arch with abnormal origin of the left subclavian artery from the common origin of both CCAs and absence of the left ICA. CT of the head revealed absence of the left carotid canal. This case highlights that the previously mentioned vascular variation can lead to significant hemodynamic changes, additional vascular malformations (aneurysms, collateral channels), and associated life-threatening conditions (subarachnoid hemorrhage or ischemia). It is particularly relevant for planning carotid artery surgery or transsphenoidal pituitary resection. Only 8 cases of right aortic arch associated with agenesis of the left internal carotid artery have been reported [14].

In one of the cases, a patient with agenesis of the ICA and perforating artery aneurysms was successfully treated with revascularization. As a result, the aneurysms shrank and disappeared following both direct and indirect bypass surgery, with the indirect bypasses developing as in Moyamoya disease (MMD) [15]. Epidemiological and clinical features of those aneurysms associated with ICA agenesis were identified based on a literature review. Aneurysms with ICA agenesis, categorized as type F in Lie's classification system or referred to as rete mirabile, sometimes localize in sites unsuitable for treatment; thus, they cannot be managed with clipping or coiling embolization. Furthermore, previous studies did not employ revascularization for aneurysm treatment [15]. If access to an aneurysm with ICA agenesis is burdensome, revascularization may be a treatment option. For patients with intracranial aneurysms, endovascular treatment is necessary. In the case of ICA agenesis, stent placement is a potential alternative. Thrombosis within the stent must be promptly treated with available tools; in this case, intra-arterial Alteplase successfully reperfused the parent vessel.

As demonstrated in one case of a patient with congenital glaucoma, the absence of the ICA may contribute ro the development of ocular ischemic syndrome. This manifests as reduced intraocular pressure in the right eye in the context of congenital absence of the left internal carotid artery [15]. The patient was treated with intravitreal injections of bevacizumab.

Table 1. Frequency of symptoms occuring in patents with ICA agenesis [2;4-6;9-30]

Symptom groups	Occurring symptoms	% n = 52 (100%)
neurological	paresis	53,85 %
	speech disorders (aphasia/dysarthria)	
	sensory disfunction (paresthesia/tingling)	
	numbness	
	weakening of the muscle strenght	
	ischemic stroke	
	subarachnoid hemorrhage	
	TIA	
	migraines	
non-specific	headaches	19,24 %
	nausea and vomiting	
otolaryngological	dizziness	11,54 %
	tinnitus	
	balance disorders	
neuro-ophthalmological	diplopia	7,7 %
	eye pain	
	amaurosis fugax	
psychiatric	memory disorders (hypomnesia)	1,9 %

Table 2. Distribution of the most common symptom groups in different age groups [2;4-6;9-30]

	0-19 y.o.	*20-35 y.o.*	*36-65 y.o.*	*powyżej 65 y.o.*
Neurological symptoms n=28 (100%)	*10,7 %*	*25%*	*57,14%*	*7,14%*
Otolaryngological symptoms en=6 (100%)	*0%*	*0%*	*83,3%*	*16,7%*
Non-specific symptoms n=10 (100%)	*10%*	*30%*	*50%*	*10%*

Conclusions

Agensesis of the ICA is a congenital and a vary rare anomaly. The overall prevelence of this condition is 0,01%. This dissorder is often asoociated with the presence of collateral pathways compensating the absence of ICA, hemodynamic disturbans of collateral vessels and cerebral aneurysms. The insidence of intracranial aneurysms in the general population is 2-4% but among patients with agenesis it inceases to 25-34% (approcimately a 12 times increase) [16]. Agenesis is primarily characterized by neurological and otolaryngological symptoms as well as nonspecific headaches, nausea, and vomiting. Additionally, isolated cases of ophthalmic and psychiatric symptoms are reported. Symptoms most commonly manifest in the 36-65 age group. Most of these symptoms appeared suddenly in patients. In some individuals, there were no accompanying comorbidities or risk factors that could lead to life-threatening conditions such as cerebral ischemia, stroke, or aneurysm. The described symptoms resulted from pathological collateral circulation that became insufficient or overloaded, leading to the formation of aneurysms or areas of ischemia. This suggests that ICA agenesis is a potential risk factor for developing cerebrovascular diseases, such as intracranial aneurysms or ischemic and hemorrhagic strokes. A summary of the data included in the review is presented in Tables 1 and 2.

Diagnosis of ICA agenesis is confirmed by observing the absence o fthe carotis canal on CT and the absence of the ICA on digital subtraction angiography (DSA) [5]. Th agenesis itself may be harmless but when discovered is treated as needed.

Discussion

Agenesis of the internal carotid artery (ICA) is a rare anomaly but its detection is crucial in the diagnosis of cerebrovascular disorders. It is worth noting that the absence of the ICA is also accompanied by the absence of the carotid canal, where it should normally reside. This finding can be helpful in differentiating ICA agenesis from other pathologies that secondarily impair flow in the artery.

In most cases, ICA agenesis may remain asymptomatic for a long period due to the presence of collateral circulation. Symptoms typically appear between the 4th and 6th decades of life as nonspecific, neurological, otolaryngological, or other symptoms. The anomaly is often detected during head and neck imaging using Doppler ultrasound, CT or MRI [14].

Symptomatic patients with ICA agenesis often present with intracranial aneurysms leading to subarachnoid hemorrhages [6]. Early detection of these aneurysms can help avoid the dangerous complications of hemorrhagic stroke. If aneurysms are located around the circle of Willis, they are treated with clipping or coiling embolization [17]. Due to the absence of the ICA, other collateral pathways develop to compensate for its flow, such as intercavernous anastomoses. Studies have shown that in some patients, ICA agenesis leads to abnormal courses of other vessels in the head and neck region [14]. This is very important during catheterization of vessels and surgeries in the head and neck area.

Our review indicates that the anomaly is most frequently detected in radiological studies, particularly CT scans. Unilateral hyperplasia of the common carotid artery may be a clue for diagnosing ICA agenesis on the opposite side. It is also important to distinguish between agenesis and occlusion of the ICA during examination, as the absence of the ICA increases the risk of aneurysms compared to the general population [6].

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