

İNSANIN ƏNG ARTERİYASININ ANATOMİK VARIABELLİYİ

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Məqalədə insanın əng arteriyasının mikroskopik strukturunun anatomik-morfoloji variantlarını və morfometrik xüsusiyyətlərini öyrənmək məqsədi ilə aparılmış tədqiqat işi haqqında məlumat verilmişdir. Tədqiqat hər iki cinsdən olan 64-77 yaş aralığında vəfat etmiş şəxslərin meyit materialları üzərində aparılmışdır. Kranial tipləri müəyyənləşdirmək, üz nahiyyəsinin dərin qatlarının anatomik preparatlarını hazırlamaq, akril plastik kütlələrindən istifadə edilməklə korroziv preparatlar hazırlamaq, arteriyaların diametrini və onların segmentlərinin dərinliyini morfometrik analiz etmək, həmçinin angioqrafik müayinə aparmaq üçün kompleks morfometrik metodlardan istifadə edilmişdir.

Əng arteriyasının 4 tipi aşkar edilmişdir: S-şəkilli (34,5%), aşağıya doğru qabarmış qövsşəkilli (20,7%), düzbucaqlı (6,9%) və qarışıq formalar ayırd edilmişdir. Arteriyanın lateral səthi qanadabənzər əzələnin daxili səthində yerləşdiyi halda onun alt çənə sinirinin şaxələri ilə qarşılıqlı münasibətlərinin 6 variantı aşkar edilmişdir. Daha geniş yayılmış variant (50%) arteriyanın sinir strukturları ilə münasibətdə lateral mövqe tutması olmuşdur. Üz sinirinin yerləşməsi ilə arteriyanın mövqeyinin uyğunluğunun 3 variantı müəyyən edilmişdir: aşağı (72,4%), yuxarı (24,1%) və eyni səviyyədə (3,5%) yerləşmə; bunlar kranial tiptən asılı olaraq 0,3 sm-dən 1,6 sm-ə qədər aralıqda yerləşirlər. Bu fərq dolixosefallarda daha aydın nəzərə çarpır. İlk dəfə olaraq, təbil arteriyasının ayrılma bucağı və diametri öyrənilmişdir. Dolixosefallarda iti və kor bucağa eyni tezliklə rast gəlinmişdir; mezosefal və braxisefallarda kor bucaq üstünlük təşkil etmişdir. Arteriyanın diametri dolixosefal tiplərdən braxisefallara doğru getdikcə azalmağa meyil etmişdir.

Beləliklə, insanın əng sümüyü aydın şəkildə fərdi anatomik-morfoloji variabelliyi ilə fərqlənir ki, bu da qismən kranial tiplə əlaqədardır. Arteriyanın topoqrafiyasının və morfometriyasının xüsusiyyətləri üz-çənə nahiyyəsində aparılan cərrahi əməliyyatların planlaşdırılmasında böyük əhəmiyyətə malik olub, əməliyyatların təhlükəsizliyinin təmin edilməsinə və nəticələrinin proqnozlaşdırılmasına kömək edə bilər.

Açar sözlər: insanın əng arteriyası, angioarxitektika, anatomik variabellik, kraniotip

Keywords: maxillary artery, angioarchitectonics, anatomical variability, craniotype

Ключевые слова: верхнечелюстная артерия, ангиоархитектоника, анатомическая вариабельность, краниотип

ANATOMICAL VARIABILITY OF THE HUMAN MAXILLARY ARTERY

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This article presents a study conducted to examine the anatomical-morphological variants and morphometric characteristics of the microscopic structure of the human maxillary artery. The study was carried out on cadaveric material obtained from deceased individuals of both sexes aged between 64 and 77 years. A complex of morphometric methods was employed to determine cranial types, to prepare anatomical specimens of the deep layers of the facial region, to produce corrosion casts using acrylic plastic compounds, to perform morphometric analysis of the diameter of the arteries and the depth of their segments, and to carry out angiographic examination.

Four types of maxillary artery courses were identified: S-shaped (34.5%), downward-convex curved (20.7%), straight (6.9%), and combined (37.9%). Six spatial variants of the relationship between the

maxillary artery and branches of the mandibular nerve were found when the artery was located on the inner surface of the lateral pterygoid muscle. The most common type (50%) was the lateral position of the artery relative to neural structures. Three spatial configurations of the artery concerning the facial nerve trunk were established: below (72.4%), above (24.1%), and at the same level (3.5%), with distances ranging from 0.3 to 1.6 cm depending on cranial type. Dolichocephalic individuals had the largest values. For the first time, the angle of origin and diameter of the anterior tympanic artery were examined about head shape. Dolichocephalic individuals displayed both acute and obtuse angles equally; in mesocephalics and brachycephalics, obtuse angles were more common. The arterial diameter progressively decreased from dolichocephalic to brachycephalic types.

The human maxillary artery shows significant individual anatomical and morphological variability, partly influenced by cranial type. The revealed features of topography and morphometry are practically important for planning surgical procedures in the maxillofacial region to improve safety and predictability.

Introduction. The maxillary artery (arteria maxillaris) is one of the two terminal branches of the external carotid artery and supplies blood to the deep structures of the face, including the maxillary bones, masticatory muscles, nasal cavity, and maxillary sinuses. Its branches, such as the infraorbital and posterior superior alveolar arteries, are especially important in planning vascular flaps, osteotomies, implantology, and microsurgical reconstruction [1–3]. For maxillofacial surgeons, detailed knowledge of the anatomy of the maxillary artery is vital because it is a primary blood supply source for deep facial tissues.

In cases of trauma or surgical procedures caused by pathology, hemorrhage – either spontaneous or postoperative – may relate to this artery. Its branches are also actively used in forming neurovascular flaps with high potential for preserving tissue function and viability [4].

Since the start of the full-scale invasion on February 24, 2022, Ukraine has faced numerous complex facial injuries due to artillery shelling, mines, drones, and missile strikes. By February 2024, over 400 patients with combat-related facial trauma had been treated at several Ukrainian medical centers (Kyiv, Lviv), mostly male patients. In more than 86% of cases, surgical wound closure or primary surgical intervention was carried out within the first 24 hours [5, 6].

Current estimates indicate that the incidence of craniomaxillofacial (CMF) trauma among injured military personnel ranges approximately from 10% to 39%, corresponding to between 10 10,000 and 46 800 cases within the Ukrainian armed forces. In civilians, facial injuries are reported in roughly 26% of wounded individuals, totaling an estimated 5, 150 cases [7].

Due to the surge in combat-related facial

injuries, Ukrainian maxillofacial surgeons have faced the challenge of performing both primary and secondary reconstructions of complex injuries, including microsurgical reconstructions, implantations, and the use of CAD/CAM technologies. No other recent European war has confronted the medical system with such a high volume and complexity of craniomaxillofacial trauma. This makes Ukraine's current experience a unique and pioneering platform for adopting advanced technologies and anatomical knowledge in vascular anatomy and reconstructive surgery [7, 8].

The purpose of the study was to investigate the anatomical and morphological variability and morphometric features of the human maxillary artery, considering craniometric parameters, to enhance anatomical visualization and improve the safety of surgical procedures in the maxillofacial region.

Research materials. The study was conducted on macroscopic specimens of the deep facial region obtained from 28 embalmed cadavers of both sexes, aged 64 to 77 years. Both the right and left sides of the face were examined. The anatomical component of the study was carried out at the cadaver facility of the Department of Topographic Anatomy and Operative Surgery of the Ukrainian Medical Stomatological Academy (Poltava). None of the cadavers had pathologies affecting the maxillary artery or other anatomical structures of the deep facial region, which allows the material to be considered representative for morphological analysis. The study was conducted by international standards for biological research and methodological guidelines, as well as the “Procedure for the Retrieval of Biological Objects from the Deceased Subjected to Forensic or Pathological Examination for Scientific Purposes” (2018).

Research methods. A comprehensive set of morphological, anatomical, and instrumental methods was applied. Anthropometry was used to

determine head shape types (dolichocephaly, mesocephaly, brachycephaly), while craniometric measurements were performed with a pelvimeter. The distance from the bifurcation of the common carotid artery (a. carotica communis) to the origin of the maxillary artery (a. maxillaris) was measured using a curvimeter. Corrosion casts were produced with acrylic plastic.

Anatomical dissection of the deep facial region was conducted using a custom-made device for macropreparation (Certificate of Rationalization Proposal No. 1755, Poltava, 1995). Morphometric parameters, including the diameter of the maxillary artery and its branches, were measured with a protractor. Macro- and micropreparations were documented using a digital camera. Additionally, twelve angiograms of patients with maxillofacial pathology were analyzed, obtained from the archives of the Department of X-ray Endovascular Surgery, Interventional Cardiology, and Reperfusion Therapy at the Shalimov National Institute of Surgery and Transplantology, National Academy of Medical Sciences of Ukraine (Kyiv).

Statistical analysis was performed using Statistica 13 and Microsoft Excel 2016. Descriptive statistics (mean, standard deviation, minimum, maximum) were calculated, and one-way ANOVA was applied to assess differences between groups

based on craniometric features. Statistical significance was set at $p < 0.05$.

Data processing was conducted using modern principles of biomedical statistics, following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for reporting observational studies and the AQUA (Anatomical Quality Assurance) checklist for anatomical research.

Research results and discussion. The course of the maxillary artery (a. maxillaris) shows considerable variability, reflecting its anatomical adaptability to surrounding structures in the deep facial region. Most often, the artery has an S-shaped configuration, seen in 34.5% of specimens. A curved course with an inferior convexity was observed in 20.7% of cases, while a straight course was noted in 6.9%. A combined arterial course appeared in 37.9% of cases. The greatest morphological variability of the artery was found in individuals with a dolichocephalic skull type, which accounted for 81.8% of all identified course variants. Quantitative morphometric data for the main trunk of the maxillary artery are provided in the **Table**.

Table. Morphometric parameters of the maxillary artery (a. maxillaris) trunk depending on cranial type

Parameter	Cranial type	Mean $\pm$ SD	min-max	n	p (ANOVA)
L, °	Dolichocephalic	51,5 $\pm$ 6,5	40–65	24	0,013*
	Mesocephalic	80,5 $\pm$ 5,5	70–92	22	
	Brachycephalic	62,2 $\pm$ 5,8	50–74	22	
d1, sm	Dolichocephalic	7,25 $\pm$ 2,75	3,1–10,8	24	ns
	Mesocephalic	7,28 $\pm$ 0,53	6,4–8,1	22	
	Brachycephalic	6,55 $\pm$ 0,95	5,2–8,0	22	
d2, sm	Dolichocephalic	1,10 $\pm$ 0,45	0,80–2,20	24	<0,001*
	Mesocephalic	2,15 $\pm$ 0,35	1,80–2,50	22	
	Brachycephalic	2,75 $\pm$ 0,40	2,30–3,20	22	
d3, sm	Dolichocephalic	2,91 $\pm$ 1,29	1,1–4,5	24	ns
	Mesocephalic	3,13 $\pm$ 0,27	2,8–3,5	22	
	Brachycephalic	3,80 $\pm$ 1,50	2,1–5,2	22	
d4, sm	Dolichocephalic	2,64 $\pm$ 0,66	1,5–3,8	24	0,005*
	Mesocephalic	3,00 $\pm$ 0,80	2,0–4,5	22	
	Brachycephalic	4,24 $\pm$ 1,24	2,9–6,1	22	
d5, sm	Dolichocephalic	5,80 $\pm$ 0,80	4,5–7,0	24	0,011*
	Mesocephalic	4,25 $\pm$ 0,95	3,1–5,6	22	
	Brachycephalic	4,55 $\pm$ 0,35	3,9–5,1	22	

Notes: L – angle between the origin of the maxillary artery (a. maxillaris) and the common carotid artery (a. carotica communis) relative to the superficial temporal artery (a. temporalis superficialis); d1 – distance from the bifurcation of the common carotid artery (a. carotica communis) to the initial segment of the maxillary artery (a. maxillaris); d2 – depth of the initial segment of the maxillary artery (a. maxillaris) from the face surface; d3 – distance from the initial segment of the maxillary artery (a. maxillaris) to the greater wing of the sphenoid bone (ala major ossis sphenoidalis); d4 – distance from the initial segment of the maxillary artery (a. maxillaris) to the temporomandibular joint (articulatio temporomandibularis); d5 – distance from the initial segment of the maxillary artery (a. maxillaris) to the mandibular body (corpus mandibulae); SD – standard deviation; n – number of observations; ns – difference is statistically non-significant. * – $p < 0.05$, statistically significant difference (according to ANOVA).

The relationship between the maxillary artery (a. maxillaris) and the mandibular nerve branches – lingual (n. lingualis) and inferior alveolar (n. alveolaris inferior) – is of clear practical importance for dental and oncologic surgery in the deep facial region. When the artery lies on the medial surface of the lateral pterygoid muscle (musculus pterygoideus lateralis), six anatomical patterns are distinguished. The most common (50%) involves a lateral course relative to the nerve branches; in 19.4%, the artery passes medially. In 13.9%, it runs between the branches (medial to the inferior alveolar and lateral to the lingual nerve). In 8.3%, it traverses a loop of the inferior alveolar nerve and follows the lateral margin of the lingual nerve. In 5.6%, it lies lateral to the mandibular nerve trunk before division, while the rarest type (2.8%) is deeply located, medial to both the nerve branches and the pterygospinal ligament (ligamentum pterygospinale).

No association was found between these relationships and head shape, as all variants occurred with similar frequency across cranial types. The maxillary artery relative to the facial nerve (n. facialis) trunk showed three positions: superior (72.4%), inferior (24.1%), and at the same level (3.5%). In all cases, the facial nerve trunk was more superficial and posterior. The distance between them ranged from 0.3–1.6 cm (artery superior) and 0.4–1.0 cm (artery inferior), with greater values in dolichocephalic and smaller in brachycephalic skulls.

Analysis of the first branch of the mandibular segment — the deep auricular artery (a. auricularis profunda)—showed no correlation between its origin angle or diameter and head shape. Several variants of origin were identified: directly from the maxillary artery (25.5%), most often from its initial segment (41.4%), as well as from the external carotid (10.3%), transverse facial (10.4%), or superficial temporal artery (10.4%). The greatest variability occurred in brachycephalic individuals.

For the first time, the angle of origin and diameter of the anterior tympanic artery (a. tympanica anterior) were analyzed in relation to cranial type, demonstrating interdependence. In

dolichocephalic skulls, acute and obtuse angles occurred equally, whereas obtuse angles predominated in mesocephalic and brachycephalic types. The mean diameter was 0.080 ± 0.070 cm, with maximal values in dolichocephalics and decreasing toward brachycephalics.

Variant analysis showed that only 29% of anterior tympanic arteries originated as independent branches of the maxillary artery. In 37.9%, they arose independently or via a common trunk from its initial segment; in 10.3%, from the external carotid artery (a. carotis externa); in 10.5%, from the superficial temporal artery (a. temporalis superficialis); and in 12.3%, together with the deep auricular artery as a common trunk from the mandibular segment of the maxillary artery.

In maxillofacial surgery, precise knowledge of the topography of facial vascular and neural structures is essential, particularly of the maxillary artery, which plays a key role in supplying the deep facial regions. According to the literature, it is the largest branch of the external carotid artery [9]. Advances in radioendovascular surgery have improved the management of relatively rare hemorrhages, especially those originating from the maxillary artery. However, interventions in the deep facial region require thorough understanding of its anatomy and branching patterns [10, 11]. A systematic review and meta-analysis based on the Anatomical Quality Assurance (AQUA) checklist indicate a growing interest in its morphological variability. Ottone N.E. et al. (2021) [9] highlight the direct clinical relevance of these variations, particularly in modern maxillofacial surgery, where they remain a central focus of anatomical research. Yağmurlu K. et al. (2017) [12] demonstrated that the maxillary artery can be safely exposed without zygomatic osteotomy or resection of the middle cranial fossa floor, using the anterior and posterior deep temporal arteries and the pterygomandibular fissure (fissura pterygomandibularis) as landmarks. These findings underscore sustained clinical interest and the need to refine surgical approaches to improve access and visualization.

During maxillofacial procedures, particularly Le Fort I osteotomies, complications such as

pseudoaneurysm of the maxillary artery may occur, potentially causing severe delayed hemorrhage [13]. This highlights the importance of detailed anatomical knowledge and understanding of its relationships with surrounding structures for timely diagnosis and management.

Cătălin C. Dumitru, Mugurel C. Rusu, and Alexandra D. Vrapciu (2024) [14] described a rare variation in which the maxillary artery courses within the temporalis muscle (*musculus temporalis*). Early dissections suggested a prevalence of ~2%; analysis of 170 archival CT angiograms (95 males, 75 females) confirmed it in 11 cases (6.47%), including 5 bilateral, totaling 16 of 340 sides (5.58%). These findings highlight the value of preoperative CT angiography in planning facial and temporal surgeries and underscore the need to consider individual anatomical variations in the temporofacial region.

Safe and effective surgical interventions in the facial region and skull base require a thorough understanding of the functional anatomy and imaging features of the maxillary artery branches. Studying anastomoses between its segments and cerebral arteries is particularly important, as these connections may help prevent intracranial hemorrhage and neurological complications during temporofacial

procedures.

Conclusions. The maxillary artery exhibits four main courses: S-shaped (34.5%), downward-curved (20.7%), straight (6.9%), and combined (37.9%). When located on the inner surface of the lateral pterygoid muscle, six relationship types with mandibular nerve branches are identified, with the most common (50%) being lateral to the nerve branches. The facial nerve trunk lies below (72.4%), above (24.1%), or at the same level (3.5%) relative to the maxillary artery's initial segment; distances range 0.3–1.6 cm and 0.4–1.0 cm, respectively, with maximal values in dolichocephalics and minimal in brachycephalics. For the first time, the angle of origin and diameter of the anterior tympanic artery were analyzed by head shape: in dolichocephalics, angles were equally acute or obtuse, while in mesocephalics and brachycephalics, they were mostly obtuse.

Future Research Perspectives. Future studies should focus on evaluating the clinical importance of anatomical variations of the maxillary artery in high-risk surgical environments and when using advanced imaging techniques. Another promising area is digital modeling of these anatomical variants, including creating 3D navigation maps for maxillofacial surgery and clinical anatomy education.

Compliance with Ethics Requirements:

„The authors declare no conflict of interest regarding this article”

„The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law.”

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АНАТОМИЧЕСКАЯ ВАРИАБЕЛЬНОСТЬ ВЕРХНЕЧЕЛЮСТНОЙ АРТЕРИИ ЧЕЛОВЕКА

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Резюме. Было проведено исследование с целью выявления анатомо-морфологических вариантов и морфометрических характеристик макроскопического строения верхнечелюстной артерии человека. Исследование проведено на трупном материале лиц обоего пола в возрасте от 64 до 77 лет. Использован комплекс морфологических методов, включавший антропометрические измерения для определения краниального типа, анатомическое препарирование глубоких отделов лицевой области, изготовление коррозионных препаратов с применением акриловой пластмассы, морфометрический анализ диаметров артерий и длины их сегментов, а также ангиографическое исследование.

Выявлено четыре типа хода верхнечелюстной артерии: S-образный (34,5%), дугообразный с выпуклостью вниз (20,7%), прямолинейный (6,9%) и комбинированный (37,9%). При расположении артерии на внутренней поверхности латеральной крыловидной мышцы установлено шесть пространственных вариантов ее взаимоотношений с ветвями нижнечелюстного нерва. Наиболее распространенным (50%) оказался латеральный вариант положения артерии по отношению к нервным структурам. Определены три варианта пространственного расположения артерии относительно ствола лицевого нерва: ниже (72,4%), выше (24,1%) и на одном уровне (3,5%), при расстоянии от 0,3 до 1,6 см в зависимости от краниального типа. Наибольшие значения характерны для долихоцефалов. Впервые изучены угол отхождения и диаметр передней барабанной артерии с учетом формы головы. У долихоцефалов острые и тупые углы встречались с одинаковой частотой; у мезоцефалов и брахицефалов преобладали тупые углы. Диаметр артерии последовательно уменьшался от долихоцефалического к брахицефалическому типу.

Верхнечелюстная артерия человека характеризуется выраженной индивидуальной анатомо-морфологической вариабельностью, частично обусловленной краниальным типом. Выявленные особен-

ности топографии и морфометрии имеют важное практическое значение при планировании хирургических вмешательств в челюстно-лицевой области, способствуя повышению их безопасности и прогнозируемости.

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