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The possibilities of ultrasound diagnostics in assessing the structural variants of the bifurcation of the common carotid artery

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Abstract

Aim – to identify various structural variants of the bifurcation of the common carotid artery using the ultrasound imaging method, taking into account the age characteristics of patients.

Material and methods. We examined 1,061 patients (the average age was 57.0±10.7 years). Using ultrasound imaging, the anatomical variant of the bifurcation of the common carotid artery was determined, taking into account the location of the external and internal carotid arteries at the visualization level. The results were grouped according to the age and gender of the patients, statistically processed.

Results. 2,122 vascular complexes were studied (1,396 in women and 726 in men). Five main types of bifurcation structure of the common carotid artery (types A – E) were identified. Type A was the most common among all participants (up to 42%). Type B was detected in up to 35% of men and 27% of women. Type C accounted for 15%-19% of cases. Other options were estimated at 4-7%. Taking into account the age, four groups were formed for men and women. At the same time, type A was 41-43% for women, regardless of age, and 31-40% for men. Type B in men in the age group 1 was detected in 48%. Type C was 2-4% more common among women in the age groups 2 and 3. In the older age group of men, type C was 31% and type E was 12% (the most common). In other age groups, D and E types accounted for 4-7%.

Conclusion. The results obtained contribute to the development of personalized directions in the treatment of vascular diseases and help to improve minimally invasive surgical interventions.

Keywords: variant anatomy, carotid arteries, ultrasound imaging.
Conflict of Interest: nothing to disclose.

Citation
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Возможности ультразвуковой диагностики в оценке вариантов строения бифуркации общей сонной артерии

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Аннотация

Цель – используя метод ультразвуковой визуализации, выявить различия вариантов строения бифуркации общей сонной артерии с учетом возрастных особенностей пациентов.

Материал и методы. Нами обследован 1061 пациент (средний возраст составил 57,0±10,7 года). С использованием ультразвуковой визуализации определялся анатомический вариант строения бифуркации общей сонной артерии с учетом расположения наружной и внутренней сонных артерий на уровне визуализации. Полученные результаты были сгруппированы с учетом возраста и пола пациентов и статистически обработаны.

Результаты. Всего изучено 2122 сосудистых комплекса (у женщин 1396, у мужчин 726). Определены 5 основных типов строения бифуркации общей сонной артерии (типы А – Д). Тип А наиболее часто встречался среди всех участников (до 42%). Тип Б выявлялся до 35% у мужчин и 27% среди женщин. Тип В составлял 15–19% случаев. Другие варианты определялись в 4–7%. С учетом возраста были сформированы по 4 группы для мужчин и женщин. При этом у женщин независимо от возраста тип А составлял 41–43%, а для мужчин 31–40%. Тип Б у мужчин в первой возрастной группе выявлен в 48%. Тип В на 2–4% определялся чаще среди женщин в первой – третьей возрастных группах. В старшей возрастной группе мужчин тип В составил – 31% и тип Д – 12%. В других возрастных группах типы Г и Д составляли 4–7%.

Заключение. Полученные результаты способствуют развитию персонифицированных направлений в лечении сосудистых заболеваний и помогают совершенствовать малоинвазивные хирургические вмешательства.

Ключевые слова: вариантная анатомия, сонные артерии, ультразвуковая визуализация.

Конфликт интересов: не заявлен.

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INTRODUCTION

Variable anatomy of the vascular bed demonstrates the importance of systematization of knowledge for subsequent successful implementation of results into clinical practice [1, 2]. The active development of methods of intravital diagnostics and modern data processing technologies make it possible to find many new features in the structure of the vascular system [3–5]. The development of minimally invasive surgical interventions and the expansion of personalized approaches in medicine require a more in-depth and detailed assessment of the main vessels [6–8]. The neck area contains the most important main arteries, which are often the site of development of dangerous hemodynamic disorders [9, 10]. Ultrasound diagnostics at the current stage of its development allows not only to evaluate the structure of the vascular wall and hemodynamic parameters, but also to obtain extensive information about the anatomy in the field of visualization [11], and the risk of developing cardiovascular diseases [12–14].

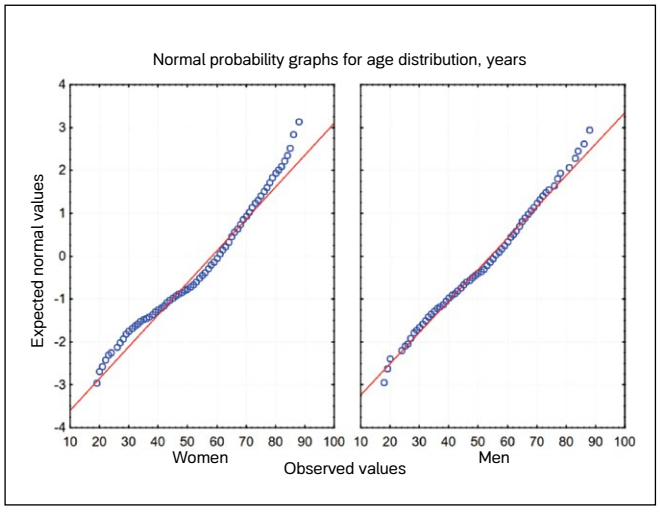

Figure 1. *Graphs of the normal probability distribution of participants by age, taking into account the gender in the observation (the Shapiro – Wilk W test for women w=0.9674, p=0.0000; for men w=0.9893, p=0.00004).*

Рисунок 1. *Графики нормального вероятностного распределения участников по возрасту с учетом пола в наблюдении (критерий Шапиро – Уилка для женщин w=0,9674, p=0,0000; для мужчин w=0,9893, p=0,00004).*

AIM

Using the ultrasound imaging method, taking into account the age characteristics of patients, to identify various structural variants of the bifurcation of the common carotid artery.

MATERIAL AND METHODS

The study was conducted using the SonoAce R7 and Logiq F6 ultrasound diagnostic systems in an outpatient setting. Linear multifrequency sensors were used for visualization.

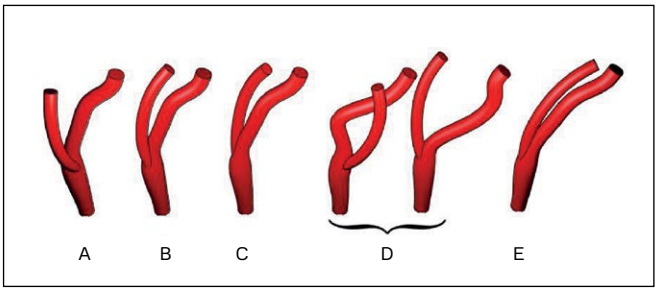

Figure 2. *Structural variants of the bifurcation region of the common carotid artery in the observation.*

Рисунок 2. *Варианты строения области бифуркации общей сонной артерии в наблюдении.*

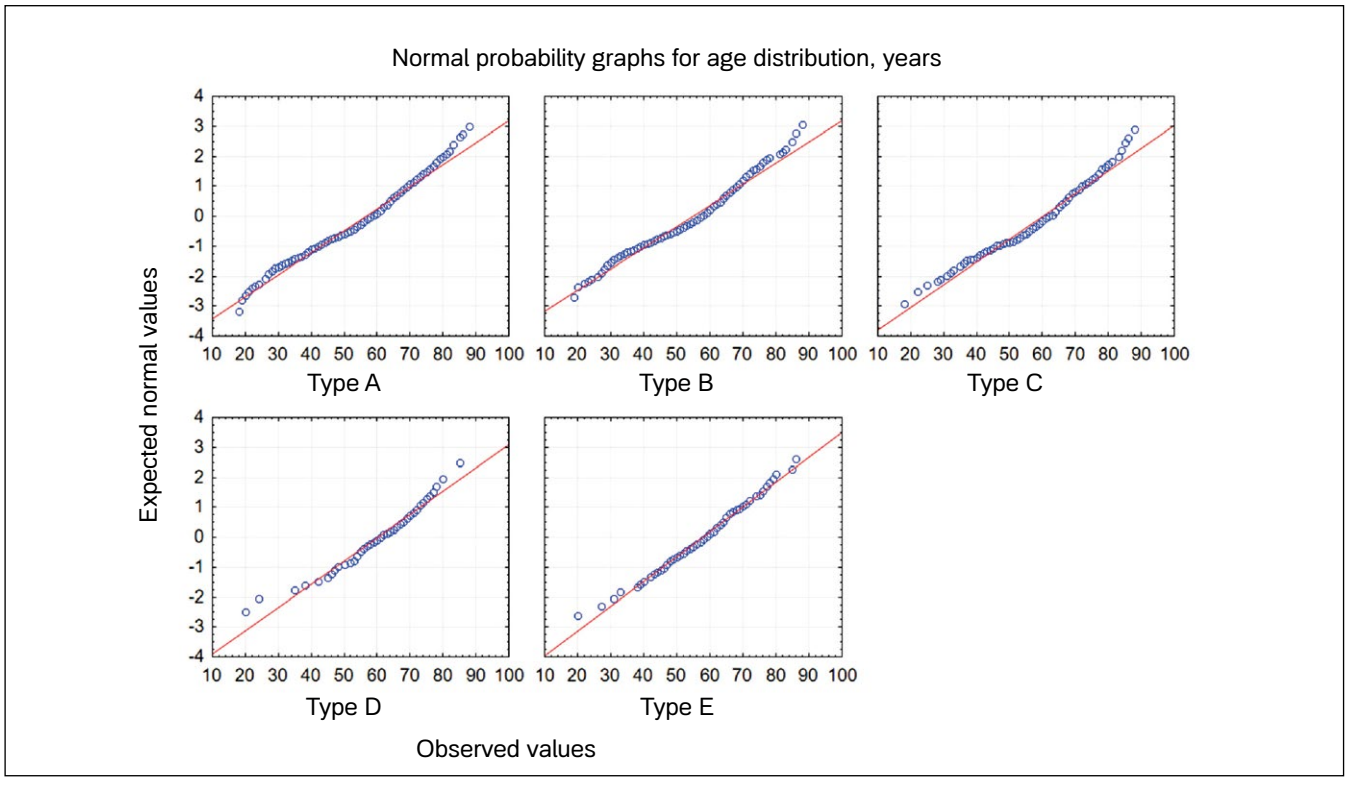

Figure 3. *Graphs of the normal probability distribution of participants by age, taking into account the type of structure of the bifurcation of the common carotid artery (Shapiro – Wilk W test: type A w=0.9787, p=0.0000; type B w=0.9729, p=0.0000; type C w=0.9701, p=0.0000; type D w=0.9622, p=0.0044; type E w=0.9913, p=0.4966).*

Рисунок 3. *Графики нормального вероятностного распределения участников по возрасту с учетом типа строения бифуркации общей сонной артерии (критерий Шапиро – Уилка: тип А w=0,9787, p=0,0000; тип Б w=0,9729, p=0,0000; тип В w=0,9701, p=0,0000; тип Г w=0,9622, p=0,0044; тип Д w=0,9913, p=0,4966).*

A total of 1061 people (698 women and 363 men) were examined. The age of the study participants ranged from 18 to 88 years, with an average of 57.0±10.7 years.

We determined the anatomical variant of the structure of the bifurcation of the common carotid artery, taking into account the location of the external and internal carotid arteries at the level of visualization. The data were summarized in Microsoft Excel 2007 tables. Statistical data processing was performed in StatSoft Statistica 10 and IBM SPSS Statistics 20 software suites.

Type of bifurcation structure	Kolmogorov-Smirnov test with Lilliefors significance correction		
	Statistics	Degree of freedom	Significance
1.00	0.080	867	0.000
2.00	0.090	626	0.000
3.00	0.090	375	0.000
4.00	0.081	105	0.089
5.00	0.054	149	0.200

Table 1. *Normality tests for age with respect to the type of structure of the bifurcation of the common carotid artery*

Таблица 1. *Критерии нормальности для возраста с учетом типа строения бифуркации общей сонной артерии*

RESULTS

By combining data from both sides of the entire visualization, 2122 carotid bifurcations were analyzed. Among women, 1396 vascular structures were assessed, and 726 among men. A visual representation of the normal age distribution among men and women in the work is presented in **Figure 1**.

In our study, we used the original system of determining the structure of the region of carotid bifurcation [3] that comprises 5 types (Fig. 2): A – median position of the external carotid artery; B – ventral position of the internal carotid; C – lateral position of the external carotid artery; D – divergence or intersection of vessels in the bifurcation region; E – medial inclination of carotid arteries.

The general data on normal distribution of participants according to age between men and women is shown in **Fig. 3** and **Table 1**.

Type of bifurcation structure	Total number of cases			% among participants		
	Women	Men	Total	Women	Men	Total
A	586	281	867	42	39	40
B	375	251	626	27	35	30
C	266	109	375	19	15	18
D	73	32	105	5	4	5
E	96	53	149	7	7	7

Table 2. *Information on the prevalence of various vascular structural variants among all participants in the observation*

Таблица 2. *Сведения о распространенности различных вариантов строения сосудов среди всех участников наблюдения*

Parameter	Type of relative position of vessels				
	A	B	C	D	E
Number, people	207	126	63	12	12
Proportion in the group, %	49	30	15	3	3

Table 3. *Distribution of the same structural variants of the common carotid artery bifurcation on both sides among the participants in the observation*

Таблица 3. *Распределение одинаковых вариантов строения бифуркации общей сонной артерии с обеих сторон среди участников наблюдения*

General data on the occurrence of structural variants of bifurcation of the common carotid artery among participants in absolute and relative values are shown in **Table 2**.

The most frequent structural variants of bifurcation are types A and B. Type A comprises up to 40% of all observed cases, reaching 42% in women and 38% in men. Type B comprises up to one third of cases: 35% among men and 27% among women. Type C is found in one fifth of cases: 19% among women and 15% among men. Other variants of the relative position of vessels (D and E), depending on the sex of patients, were found in 4-7%.

In 420 participants of the study (164 men and 256 women) similar structural variants of bifurcation of the common carotid arteries on either side were identified, which comprises 39.6% of the total data in the observation; the general data follows in **Table 3**.

We then analyzed the results obtained taking into account the gender and age of the patients. The following groups of study participants were formed as per age periods: Group 1,

Type of bifurcation structure	Kolmogorov-Smirnov test with Lilliefors significance correction			Shapiro-Wilk W test		
	Statistics	Degree of freedom	Significance	Statistics	Degree of freedom	Significance
A	0.280	867	0.000	0.844	867	0.000
B	0.263	626	0.000	0.846	626	0.000
C	0.303	375	0.000	0.834	375	0.000
D	0.291	105	0.000	0.837	105	0.000
E	0.264	149	0.000	0.826	149	0.000

Table 4. *Normality test for the type of structure of the bifurcation of the common carotid artery with respect to the age group*

Таблица 4. *Критерии нормальности для типа строения бифуркации общей сонной артерии с учетом возрастной группы*

Age group	Kolmogorov-Smirnov test with Lilliefors significance correction			Shapiro-Wilk W test		
	Statistics	Degree of freedom	Statistics	Degree of freedom	Statistics	Degree of freedom
1	0.273	178	0.000	0.770	178	0.000
2	0.253	770	0.000	0.794	770	0.000
3	0.232	1010	0.000	0.818	1010	0.000
4	0.234	164	0.000	0.837	164	0.000

Table 5. *Normality test for the age group with respect to the type of structure of the bifurcation of the common carotid artery*

Таблица 5. *Критерии нормальности для возрастной группы с учетом типа строения бифуркации общей сонной артерии*

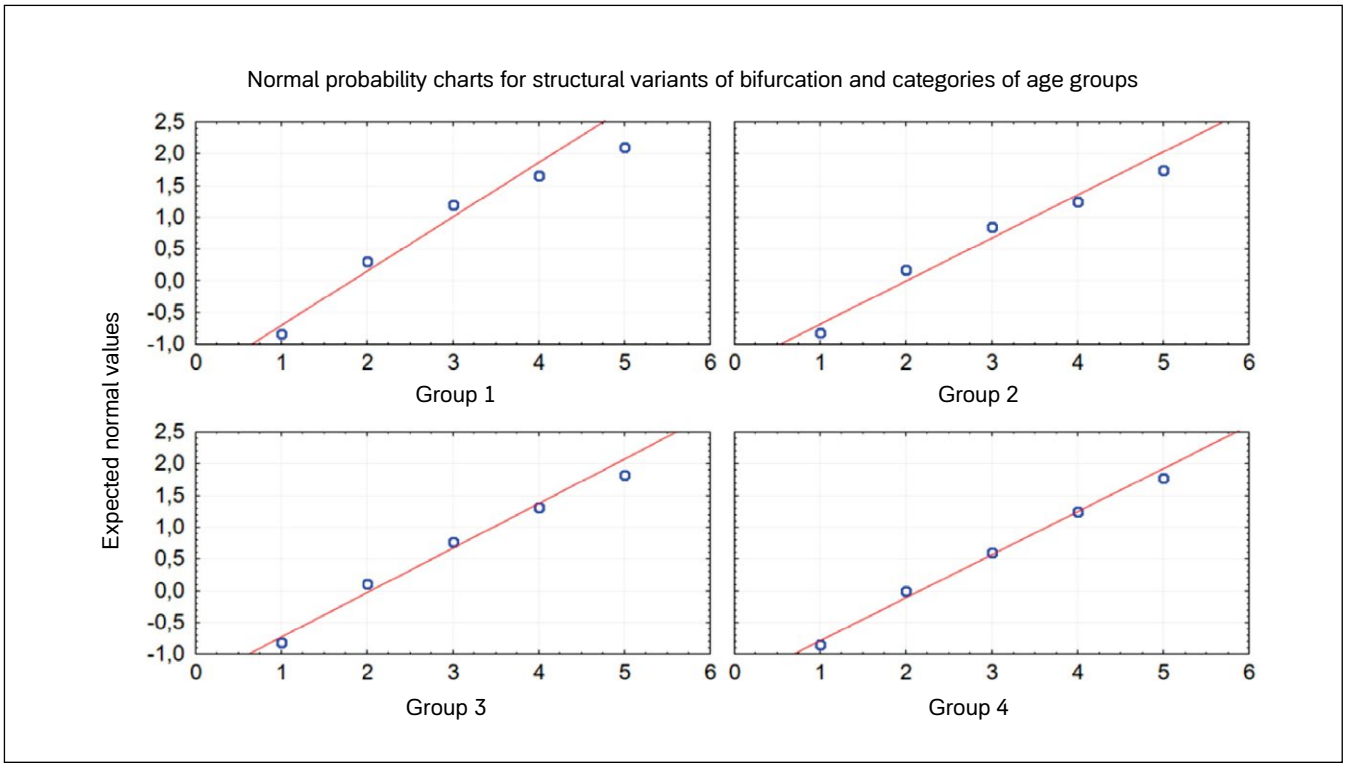

Figure 4. *Diagram of the distribution of participants, taking into account the type of structure of the common carotid artery bifurcation and age group (Shapiro – Wilk W test: group 1, w=0.7703, p=0.0000; group 2, w=0.794, p=0.0000; group 3, w=0.8183, p=0.0000; group 4, w=0.8368, p=0.0000).*

Рисунок 4. *Диаграмма распределения участников с учетом типа строения бифуркации общей сонной артерии и возрастной группы (критерий Шапиро – Уилка: первая группа w=0,7703, p=0,0000; вторая группа w=0,794, p=0,0000; третья группа w=0,8183, p=0,0000; четвертая группа w=0,8368, p=0,0000).*

Type of relative position of vessels	Women				Men			
	G 1 n=100	G 2 n=372	G 3 n=802	G 4 n=122	G 5 n=78	G 6 n=398	G 7 n=208	G 8 n=42
A	44 (44%)	159 (43%)	279 (41%)	51 (43%)	28 (36%)	157 (39%)	83 (40%)	13 (31%)
B	39 (39%)	106 (28%)	172 (26%)	22 (18%)	37 (48%)	140 (35%)	64 (31%)	10 (24%)
C	12 (12%)	60 (16%)	137 (20%)	31 (25%)	7 (9%)	50 (13%)	39 (18%)	13 (31%)
D	-	19 (5%)	32 (6%)	10 (8%)	5 (6%)	16 (4%)	10 (5%)	1 (2%)
E	5 (5%)	28 (8%)	42 (7%)	7 (6%)	1 (1%)	35 (9%)	12 (6%)	5 (12%)

Table 6. *Distribution of structural variants of the bifurcation of the common carotid artery, taking into account gender and age group*
Таблица 6. *Распределение вариантов строения бифуркации общей сонной артерии с учетом пола и возрастной группы*

youth and I adult period (men and women aged below 35); Group 2, II adult period (men over 35 and below 60, and women below 55 years of age); Group 3, elderly people (men over 60 years of age and women over 55 and below 74 years of age); Group 4, old people (above 75 years of age).

The distribution of structural variants of main vessels in the region of the common carotid artery bifurcation among participants from various age groups regardless of their sex is shown in **Fig. 4** and **Tables 4** and **5**.

The data on the number of identified types of relative position of vessels in the region of the common carotid artery bifurcation among women and men are shown in **Table 6**.

Most frequently, Type A was found among women, comprising 41-43% of the cases in all age groups. Among men, this type of relative position of vessels was found least frequently, in 31% of the cases, in Group 4.

In the male group, Type B was identified more frequently than in the female group. The largest number of cases was found in Group 1 of men (48%), and the least number in Group 4 (24%). Among women, this variant of relative position of vessels in the region of the common carotid artery bifurcation was 39% of the cases in Group 1, whereas the least number of cases, 18%, was found in age Group 4.

Type C in Groups 1, 2 and 3 was mound 2-4% more frequently in women. In Group 4 among men, Type C was found most frequently comprising 31%.

The remaining types of relative position of vessels (D and E) made up to 4–7% of the cases across the age groups. The greatest value for Type E was found in the among men reaching 12% in Group 4. Type D was not found in women in age Group 1.

DISCUSSION

The study of the variable anatomy of the main arteries of the neck is performed by different teams of specialists. Morphological studies based on pathological examinations are of special interest. P.A. Samptesov et al. (2012) report the data of morphological examination of the main arteries considering individual specifics of the shape of the neck based on examination of bodies of 97 men [15]. F. Hojaij et al. (2019) uses the data of 50 pathological examination to study anatomic peculiarities in the relative position of the carotid arteries, jugular vein and the vagal nerve [16]. The undisputed advantage of pathological examination is its unbiased nature, the possibility of detailed documentation of the study process, and the possibility of append the results of studies with histological specimens. Unfortunately, autopsy data do not always allow for a full assessment of the functional relationships that are most relevant in clinical practice.

Great attention is paid to descriptions of dimensional characteristics of the main arteries of the neck [1]. Many clinical studies dwell, in much detail, on questions of diagnosing [2] or specifics of surgical treatment [4, 6]. The variable anatomy of the main arteries is of particular importance when planning high-tech and minimally invasive surgical interventions [17–19].

The classification of relative position of vessels, presented by us, was originally developed to assess the variability of the main arteries when studying images obtained by magnetic resonance tomography [3], however, in the process of practical work it proved well in performing ultrasonic visualization.

In vascular surgery, the area of intravascular interventions is rapidly developing [9], allowing for the individual characteristics of the anatomy of the main arteries to be taken into account directly at the operating table. Methods of minimally invasive surgery require refined knowledge of individual variability of the bloodstream. The region of the bifurcation of the common carotid artery includes one of the most important reflexogenic zones of vegetative innervation, and is the location of the most frequent diagnostic of significant atherosclerotic changes at the level of the vessel wall. Contemporary methods of processing of diagnostic information using computers enable the use of methods of computer analysis, create realistic three-dimensional models facilitating surgery planning [20, 21].

The data on age and sex factors associated with varying anatomy of the main arteries in the region of bifurcation presented in this paper, combined with ultrasonic visualization, enable improvement of personalized approach in medicine [11].

Our study demonstrates the possibility of practical implementation if a simple, straightforward and effective method to determine anatomic variants of the structure of the common carotid artery bifurcation. The relatively large scope of research allowed for a precise identification of the rare types (D and E) and formation of participant groups with respect to their age.

CONCLUSION

Our study presents the possibilities of ultrasonic visualization of the anatomical variations in the structure of the common carotid artery bifurcation. The considerable size of

our sampling allowed showing the correlations of prevalence of the different anatomic variants among men and women, and taking into account the factor of the patients' age.

In general, typical variants of relative position of the vessels (types A and B) are most frequent with Type A being prevalent among women. Type B variant of the vessel relative position is seen more often in young men. Type C, in its turn, is more often identified in both men and women, as the age progresses. Rare types of vessel position (D and E) are identified in 4-7% of the cases; and only in men of II adult period type E comprised 12% cases.

The presented data are relevant for assessing the variable anatomy of the main arteries of the neck, allowing development of personalized directions in the treatment of vascular diseases and improvement of minimally invasive surgical interventions.

ADDITIONAL INFORMATION

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Conflict of interest. The authors declare that there are no obvious or potential conflicts of interest associated with the content of this article.

Compliance with Ethical Standards

The authors confirm that the rights of the people who participated in the study were respected, including obtaining informed consent where necessary. The study protocol was approved by the local Ethics Committee of the Orel State University named after I.S. Turgenev (protocol No. 25 dated November 16, 2022).

Contribution of individual authors. A.S. Moshkin – organization of the theoretical and clinical part of the research, conducting the research, editing of the manuscript. V.N. Nikolenko – design of the research; interpretation of the research results. M.A. Khalilov – statistical data processing; editing of the manuscript. L.V. Gavryushova – coordination of the clinical part of the research, interpretation of the research results. L.V. Moshkina – statistical processing, editing the manuscript. Zhi Li – statistical data processing; interpretation of research results.

All authors gave their final approval of the manuscript for submission, and agreed to be accountable for all aspects of the work, implying proper study and resolution of issues related to the accuracy or integrity of any part of the work.

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Соответствие нормам этики

Авторы подтверждают, что соблюдены права людей, принимавших участие в исследовании, включая получение информированного согласия в тех случаях, когда оно необходимо. Протокол исследования был одобрен локальным этическим комитетом ФГБОУ ВО «Орловский государственный университет имени И.С. Тургенева» Министерства науки и высшего образования РФ (протокол № 25 от 16 ноября 2022 г.).

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Все авторы одобрили финальную версию статьи перед публикацией, выразили согласие нести ответственность за все аспекты работы, подразумевающую надлежащее изучение и решение вопросов, связанных с точностью или добросовестностью любой части работы.

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