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Клиническая анатомия сосудов подколенной области

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АННОТАЦИЯ

Введение. Современным стандартом неинвазивной диагностики сосудистой системы является дуплексное сканирование. Вариабельность сосудистой анатомии предъявляет высокие требования к её знанию у врачей ультразвуковой диагностики.

Цель. Уточнить варианты клинической анатомии сосудов подколенной области с помощью дуплексного сканирования и анатомического препарирования.

Материалы и методы. В работе были использованы данные, полученные при дуплексном сканировании артерий и вен нижних конечностей у пациентов без патологии сосудистой системы нижних конечностей, проходивших обследование сосудистой системы: 200 пациентов в возрасте 18–92 года. В качестве контроля были взяты данные анатомического препарирования 50 ампутированных нижних конечностей с предварительным заполнением венозной системы синтетическим гелем синего цвета.

Результаты. По данным анатомического препарирования, два ствола подколенной вены в дистальной части подколенной области были идентифицированы в 86,0% наблюдений. Типичное впадение малой подкожной вены с формированием сафенопоплитеального соустья встретилось в 60,0% случаев. По данным дуплексного сканирования, в 1,9% наблюдений была выявлена высокая бифуркация подколенной артерии. Два ствола подколенной вены в дистальной части подколенной области встретились в 82,4% случаев, причём медиальный ствол практически всегда был больше латерального. Впадение малой подкожной вены в подколенную вену встретилось в 63,0% случаев. В 7,2% наблюдений она впадала в одну из внутримышечных вен. В 0,95% наблюдений была выявлена перфорантная вена в подколенной области. Суральные вены идентифицировались у всех пациентов — по две вены с медиальной и латеральной поверхностей, располагаясь по бокам от суральных артерий и формируя единый ствол перед слиянием с подколенной веной.

Выводы. Результаты исследования выявили следующие варианты анатомии сосудов подколенной области: два ствола подколенной вены ниже щели коленного сустава идентифицируются с частотой от 85,7% до 86,0%; высокая бифуркация подколенной артерии встречается в 1,9% наблюдений; сафенопоплитеальное соустье встречается с частотой от 60,0% до 63,0%; в 0,95% наблюдений были выявлены перфорантные вены подколенной области; при этом малая подкожная вена не формирует сафенопоплитеального соустья.

Ключевые слова: *вариантная анатомия; подколенная вена; подколенная артерия; сафенопоплитеальное соустье; перфорантная вена*

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Clinical Anatomy of Vessels of Popliteal Region

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ABSTRACT

INTRODUCTION: A modern standard for noninvasive diagnostics of the vascular system is duplex scanning. The knowledge of variability of vascular anatomy is essential for ultrasound doctors.

AIM: To clarify variants of the clinical anatomy of vessels of the popliteal region using duplex scanning and anatomical preparation.

MATERIALS AND METHODS: The work used data of duplex scanning of the arteries and veins of the lower extremities of patients without pathology of the vascular system of the lower extremities, who underwent examination of the vascular system: 200 patients aged from 18 to 92 years. As control, the data of anatomical preparation of 50 amputated lower extremities were taken, with preliminary filling the venous system with a blue synthetic gel.

RESULTS: In the course of anatomical preparation, two trunks of the popliteal vein were identified in the distal popliteal region in 86.0% of observations. A typical drain of the small saphenous vein with formation of the saphenopopliteal junction was encountered in 60.0% of cases. In duplex scanning, a high bifurcation of the popliteal artery was detected in 1.9% of observations. The two trunks of the popliteal vein in the distal part of the popliteal region were encountered in 82.4% of cases, and the medial trunk was almost always larger than the lateral one. The small saphenous vein drained into the popliteal vein in 63.0% of cases. In 7.2% of observations, it drained into one of the intramuscular veins. In 0.95% of observations, a perforator vein was identified in the popliteal region. The sural veins were identified in all the patients — two on the medial and lateral surface positioned at the sides of the two trunks of the sural arteries, forming a single trunk before confluence with the popliteal vein.

CONCLUSIONS: TThe study revealed the following anatomic variants of vessels of the popliteal region: two trunks of the popliteal vein below the knee joint cleft in 85.7% to 86.0% of observations; a high bifurcation of the popliteal artery in 1.9%; saphenopopliteal junction in 60.0% to 63.0%; perforator veins of the popliteal region in 0.95% of observations; upon that, the small saphenous vein does not form the saphenopopliteal junction.

Keywords: *variant anatomy; popliteal vein; popliteal artery; saphenopopliteal junction; perforator vein*

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ECO•VECTOR

LIST OF ABBREVIATIONS

ATA — anterior tibial artery
ATV — anterior tibial vein
CT — computed tomography
DS — duplex scanning
PA — popliteal artery
PfV — perforator vein
PTA — posterior tibial artery
PTVs — posterior tibial veins
PV — popliteal vein
SPJ — saphenopopliteal junction
SSV — small saphenous vein

INTRODUCTION

Thromboses of deep, superficial veins and arteries of the lower extremities present the most important problem of modern phlebology and vascular surgery. According to the Association of Phlebologists of Russia, the incidence of thrombosis of the superficial and deep venous systems of the lower extremities in our country reaches 0.3–1.6 cases per thousand people [1, 2]. The most severe complication of thrombosis of the venous systems of the lower extremities is pulmonary embolism, therefore, of high importance is their high quality diagnosis [1, 3]. Another problem is arterial thrombosis of the lower extremities, surgical treatment of which is not always successful due to, among other things, variant anatomy of vessels not identified at the diagnostic stage.

The modern standard for examining patients with superficial or deep vein thrombosis, arterial thrombosis, and also with chronic diseases of the arteries and veins of the lower extremities is duplex scanning (DS) [4, 5]. The study at the level of the arteries and the femoropopliteal and popliteal-tibial segments of the deep veins, as well as superficial veins, is conducted using a linear sensor. *One of the most difficult areas to study from the point of view of anatomy is the popliteal region [5].*

When examining the popliteal vessels, the first thing of interest in patients diagnosed with deep vein thrombosis (DVT) is the number of trunks of the popliteal vein (PV), their topography and patency, and in patients with arterial pathology, the level of bifurcation of the popliteal artery (PA) and its patency, since these factors determine the choice of access in surgical treatment. DS is performed along a vertical line drawn through the middle of the popliteal region, that is, along the line of projection of the popliteal vessels [5].

Normally, the PA and PV are presented by single trunks, with the PV running over the artery at the medial side in the distal part and at the lateral side in the proximal part. In the canalis popliteus (the upper third — 3–7 cm below the knee joint), PA divides into the anterior tibial artery (ATA) and posterior tibial artery (PTA), which are accompanied by homonymous veins. The anterior tibial artery and homonymous veins penetrate the anterior intermuscular bed of the leg through the opening in the interosseous membrane, posterior tibial vessels remain in the canalis popliteus.

Ultrasound doctors divide the popliteal vessels into three segments:

P1 — from the place of exit from the adductor canal to the upper edge of patella,

P2 — at the level of the knee joint cleft,

P3 — up to the level of bifurcation of PA/confluence of the anterior tibial veins (ATVs) and posterior tibial veins (PTVs) into the popliteal vein [5].

In practice, two levels of popliteal vessels are usually distinguished — above or below the knee joint cleft.

It is interesting that in clinical practice, the anatomical variants of the popliteal vessels are encountered with the popliteal vein represented by two trunks or with a high bifurcation of the popliteal artery. This creates difficulties in the diagnosis, since blood clots in the second trunk of the PV may be overlooked, and in the case of high bifurcation of the PA, the wrong access may be chosen for its isolation or the wrong vessel may be selected for distal anastomosis of the femoropopliteal bypass [6, 7]. Besides, knowledge of anatomical variants with high division of the PA is necessary when performing orthopedic operations [7].

The presence of the extramuscular sections of sural veins in the popliteal region draining into the popliteal vein, and the location of the saphenopopliteal junction (SPJ) in this area also complicate the identification of vessels. Besides, there are data on the localization of perforator veins (PfVs) in the popliteal region [8].

The **aim** of this study to clarify the clinical anatomy of the vessels of the popliteal region using duplex scanning and anatomical preparation.

MATERIALS AND METHODS

The study included 200 patients aged from 18 to 92 years without vascular pathology according to DS data obtained when undergoing examination of the vascular system on outpatient visit to the polyclinic of

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Ryazan Regional Clinical Cardiologic Dispensary. The work was approved by the Local Ethics Committee of Ryazan State Medical University (Protocol No. 14 of April 11, 2022). DS was conducted on MyLab Alpha (Esaote, Italy) and Acuson Sequoia 512 (Siemens, Germany) expert class ultrasound systems using a linear sensor with 3–15 MHz frequency and a convex sensor with 3–7 MHz frequency [1].

As control, the data of anatomical preparation of 50 amputated lower extremities of patients with obliterating atherosclerosis of arteries of the lower extremities without pathology of the venous system were taken, with preliminary filling the venous system with a blue synthetic gel.

Statistical analysis was carried out using Excel 2016 (Microsoft Corporation, USA) and SPSS 26.0 (IBM Company, USA) software. The results are presented as the arithmetic mean and the error of the arithmetic mean. The confidence level was taken to be 95% probability of difference ($p < 0.05$).

RESULTS

The results of anatomical preparation are given in Table 1.

Table 1. Anatomical Variants of Vessels of the Popliteal Region by Anatomical Preparation Data

Level of Popliteal Region	Popliteal Artery	Popliteal Vein	Sural Veins	Saphenopopliteal/ Saphenosural Junction	Perforator Vein
	Number of trunks, n/%				
Above knee joint cleft	1/100	1/100	4/100	1/60	–
Below knee joint cleft	1/100	2/86	4/100	1/6	–

In the anatomical preparations, no anatomical variants of the PA were found. The PV at the level above the knee joint cleft was also represented by one trunk, but below the interarticular knee joint cleft, two PV trunks were identified in 86.0% of cases, and in 46.5% this was a true duplication, i.e. division of a single trunk of the PV formed by the confluence of the PTV and ATV, into two vessels, located at the sides of the PA and then uniting immediately above the knee joint (Figure 1); in 53.5%, a high formation of the PV was revealed, i.e. the confluence of the PTV and ATV at the level of the knee joint cleft (Figure 2).

A typical drain of the small saphenous vein (SSV) with formation of SPJ occurred in 60.0% of cases, in 6.0% of cases the SSV drained into one of sural veins (Figure 2A). Sural veins occurred in all preparations in the quantity of four vessels (Figures 1, 2). The DS results are given in Table 2.

Table 2. Anatomical Variants of the Vessels of the Popliteal Region by Duplex Scanning

Level of Popliteal Region	Popliteal Artery	Popliteal Vein	Sural Veins	Saphenopopliteal/ Saphenosural Junction	Perforator Vein
	Number of trunks, n/%				
Above knee joint cleft	1/100	1/100	4/100	1/63,0	0,95
Below knee joint cleft	1/100	2/85,7	4/100	1/7,2	–

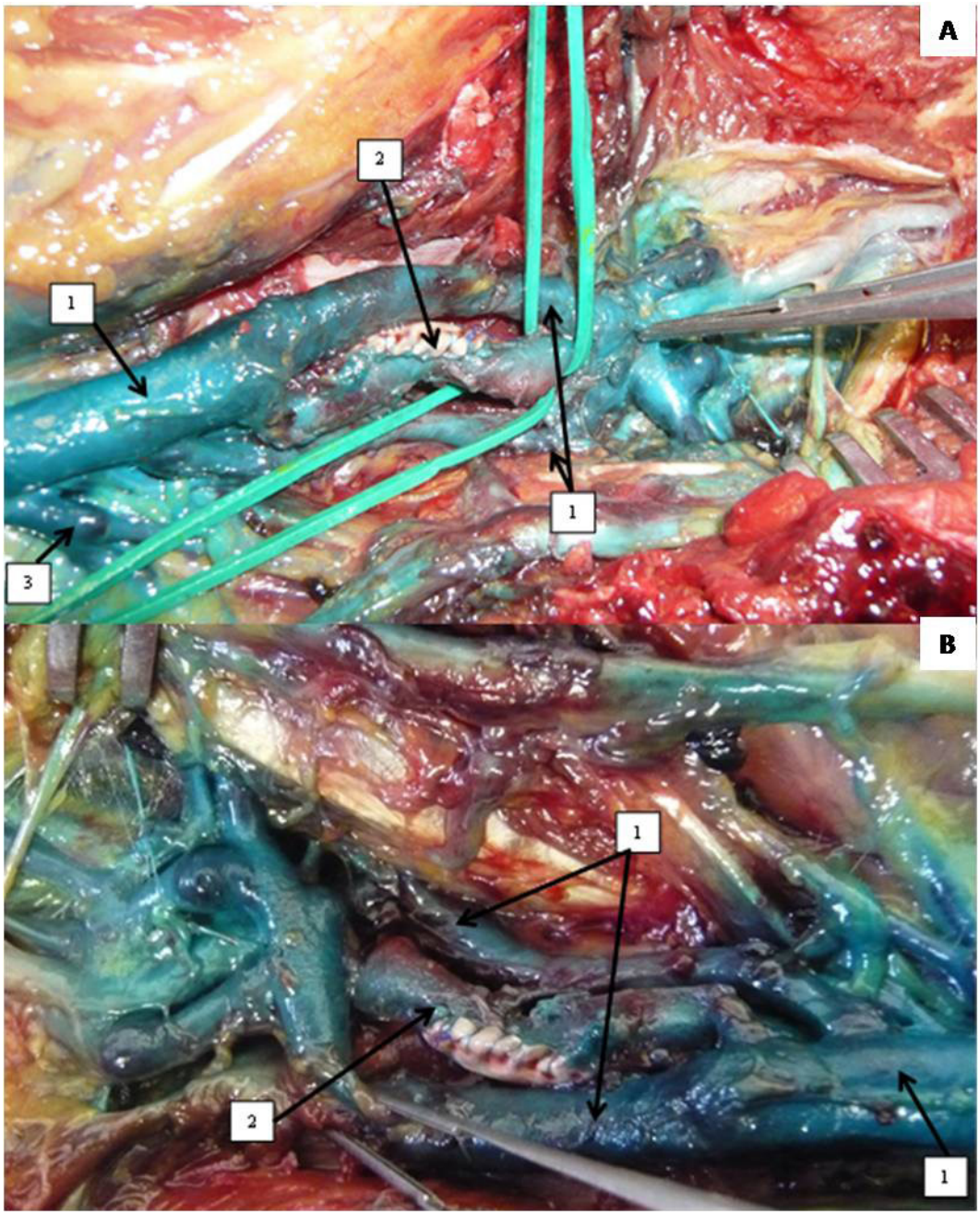

Fig. 1. An anatomical preparation of the topography of the vessels of the popliteal region (photos of the authors).
Notes: (1) Popliteal vein; (2) Popliteal artery; (3) Sural veins. The mouths of the posterior tibial and anterior tibial arteries are on the green tourniquets

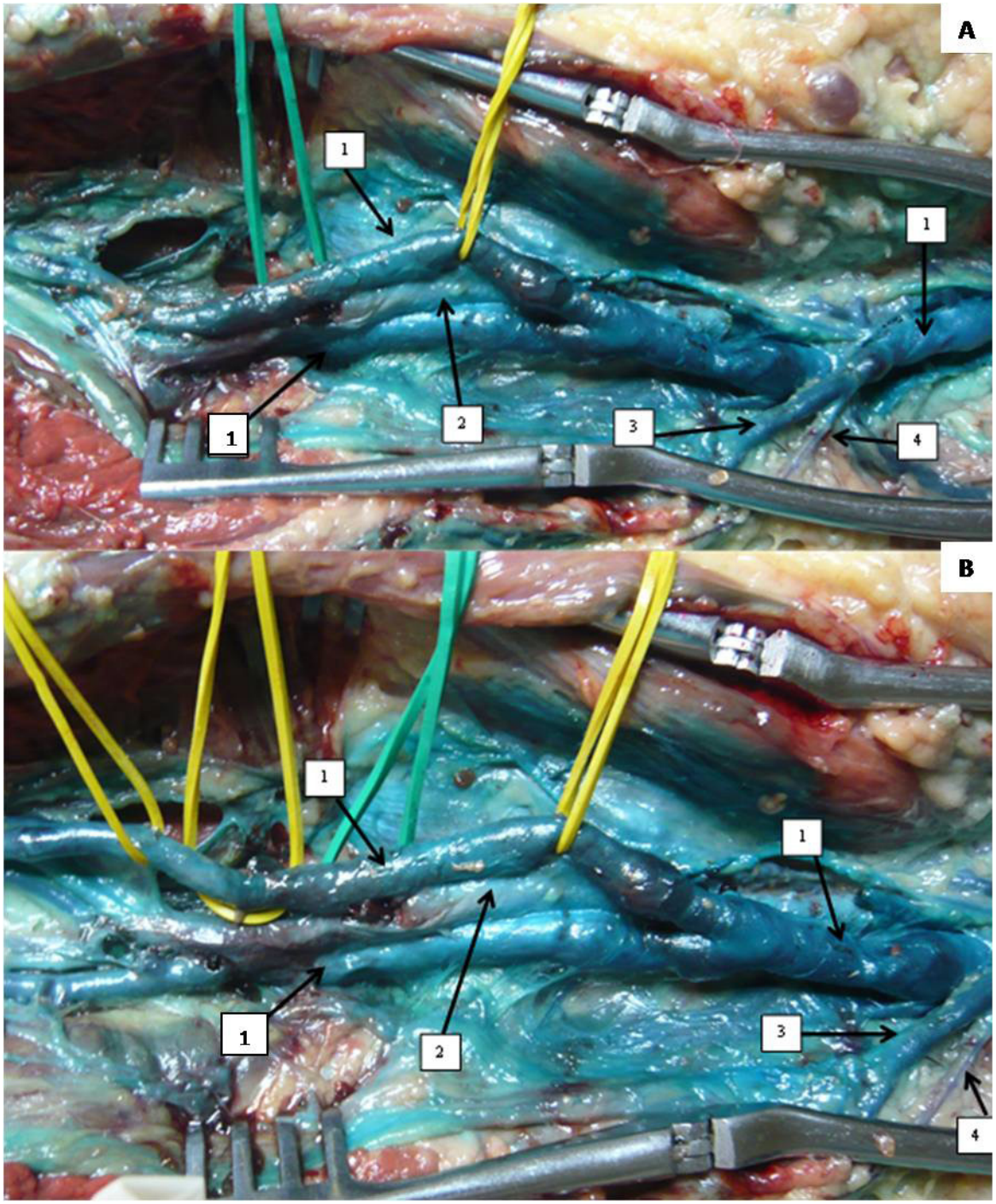

Fig. 2. An anatomical preparation of the topography of the vessels of the popliteal region (photos of the authors).
Notes: (1) Popliteal vein; (2) Popliteal artery; (3) Sural veins; (4) Small saphenous vein. The mouth of the anterior tibial artery is on the green tourniquet, the entry of the popliteal vein is on the yellow ones.

On duplex scans, PA was always represented by one trunk, in 4 patients (1.9%), high bifurcation of PA was found at the level of the proximal part of the popliteal fossa — 2 cm above the knee joint cleft. It is important to note that ATA runs in the initial parts isolated from the anterior tibial veins at an angle approximate to 60° relative to the course of PA (while the ATV runs at an angle approximate to 90°), and connects to the ATV only in the anterior intermuscular bed of the leg (Figure 3).

Interesting data on the location of PA were obtained by DS. In the proximal part of the popliteal fossa, PA was located relative to the midline, and in the distal part it was displaced laterally and coursed 1.51 ± 1.4 cm medial to the head of fibula (Figure 4).

Two trunks of the PV in the distal part of the popliteal region were found in 85.7% of cases, and the vessel located medially from the PA was almost always larger than the one located laterally (Figure 5). Statistical analysis showed no statistically significant difference between the data of anatomical preparation and DS for this feature (p = 0.959).

The SSV drained into the popliteal vein with the formation of the SPJ in 63.0% of cases, in 7.2% of cases the SSV drained into one of the sural veins, which had no statistically significant difference from the data of anatomical preparation (p = 0.708, p = 0.775, respectively). Interestingly, in 0.95% of cases, a PfV was found that opened into the PV. Upon that, the SSV passed in close proximity to it, but did not connect to it and did not form the SPJ. In 29.8% of cases, the SVJ did not form connections with the deep veins in the area of the popliteal fossa.

The sural veins were visualized in all patients, usually two on the medial and lateral surfaces, forming a single trunk before joining the PV and located at the sides of the sural arteries. It is important to note that the sural artery is a fairly large vessel, 2.8 ± 0.3 mm in diameter, which suggests its significant role in the development of collateral circulation in patients with peripheral atherosclerosis (Figure 6).

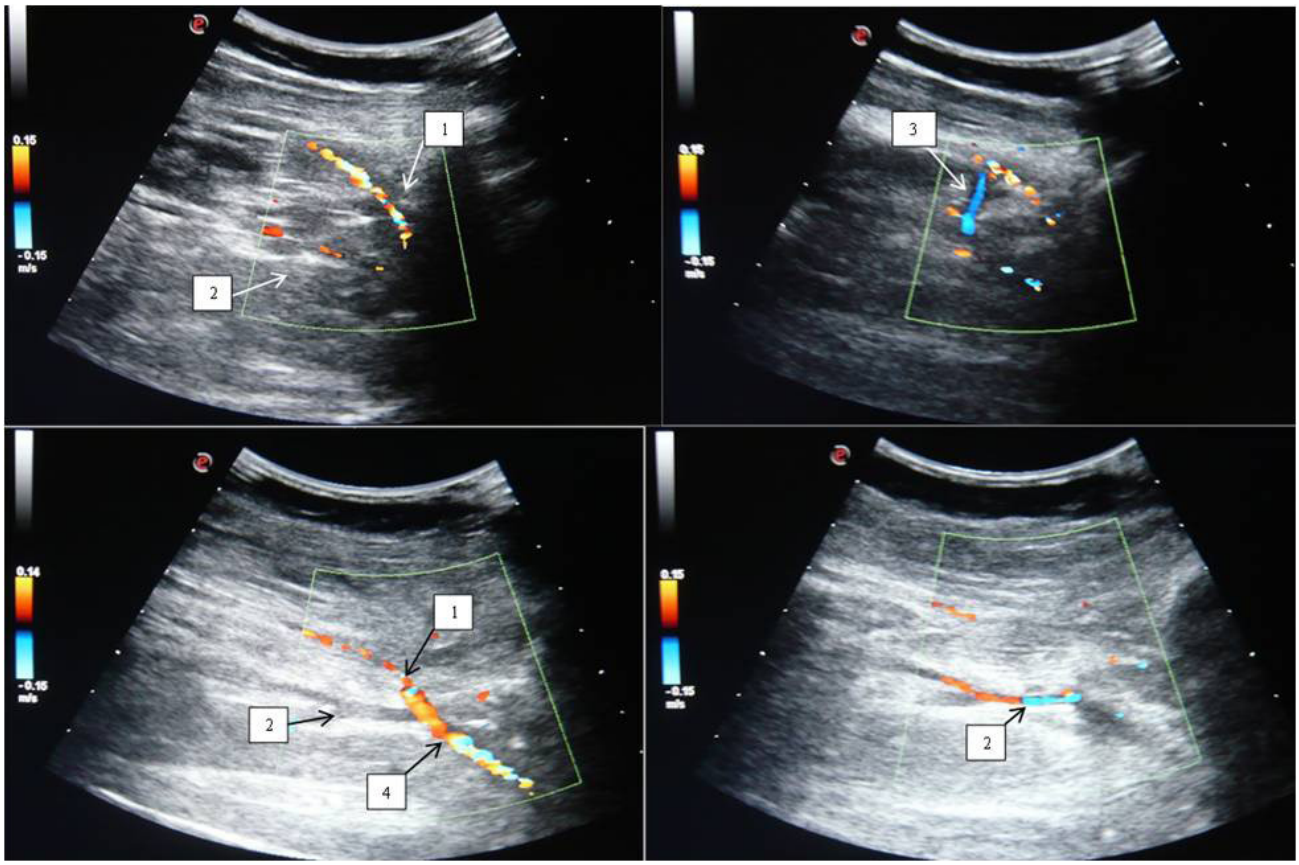

Fig. 3. Duplex scan of a patient with a high division of the popliteal artery.
Notes: (1) Anterior tibial artery; (2) Posterior tibial artery; (3) Anterior tibial veins; (4) Popliteal artery.

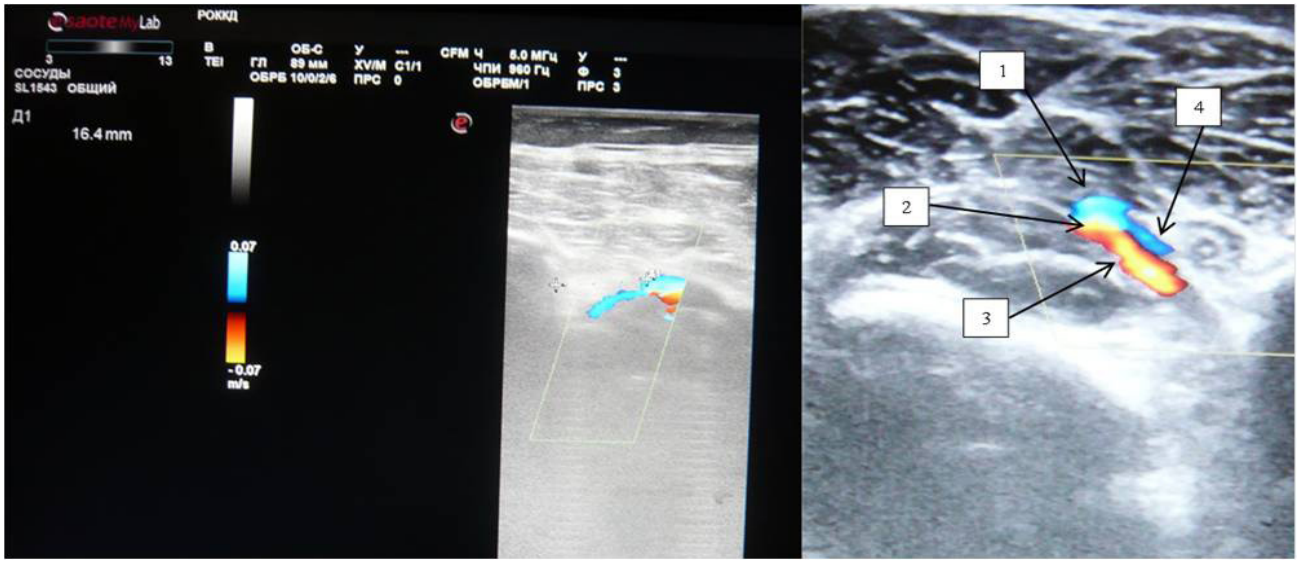

Fig. 4. Duplex scan of the bifurcation region of the popliteal vessels — the distance from the head of fibula is 16.4 mm.
Notes: (1) Popliteal vein; (2) Popliteal artery; (3) Anterior tibial artery; (4) Anterior tibial veins.

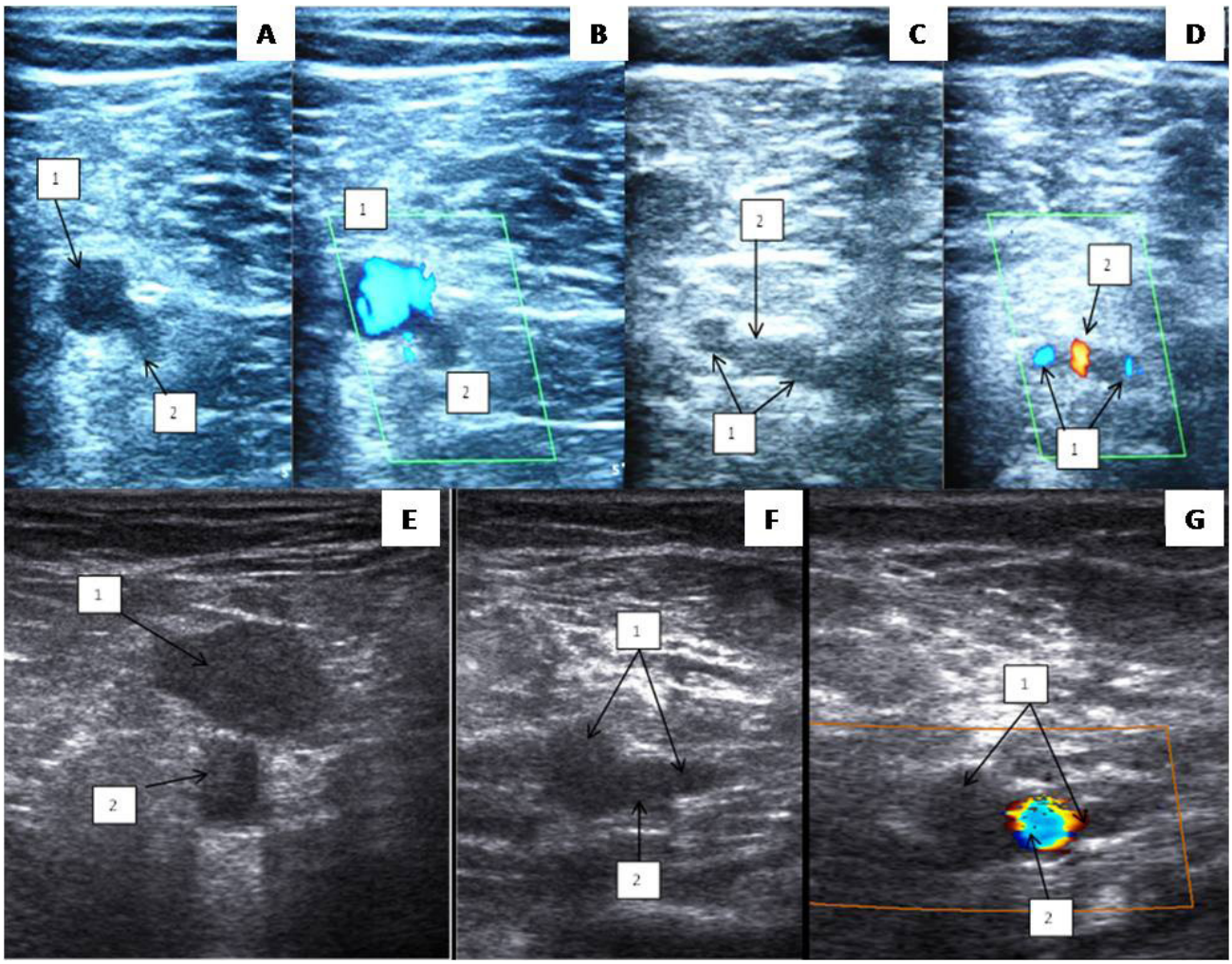

Fig. 5. Duplex scan of the popliteal vein: (A, B, E) topography of the popliteal vein (level above the knee joint fissure); (C, D, F, G) two trunks of the popliteal vein below the knee joint cleft.
Notes: (1) Popliteal vein; (2) Popliteal artery.

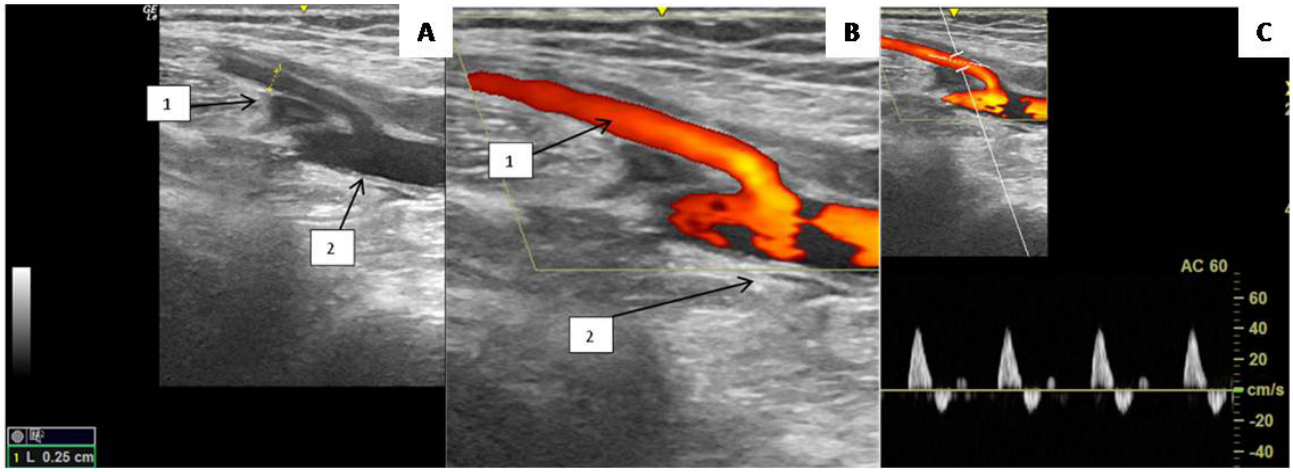

Fig. 6. Duplex scan of the sural artery; (A) B-mode; (B) Color Doppler mapping mode; (C) Spectral Dopplerography mode.
Notes: (1) Popliteal artery; (2) Sural artery.

DISCUSSION

It is well known that the diagnostics of vascular diseases is not always easy, especially for young doctors. The main cause of difficulty is the variant anatomy of the vascular system. Therefore, the doctor's task is, first, to correctly identify vessels, and, second, to directly describe pathological process and make a diagnosis.

High bifurcation of PA is one of the commonest variants of PA anatomy [5]. According to the data of studies based on anatomical preparation, the incidence of high division of PA to ATA and PTA ranges from 0% to 5% [9–11]. Be reminded that normally PA divides to ATA and PTA at the level of the lower margin of the popliteal muscle.

According to angiographic examinations (computed tomography (CT) angiography or X-ray contrast angiography), high origin of the ATA occurs with a frequency of 1.2% to 5.2% [12–14].

It is interesting that when searching for works devoted to the variant anatomy of the popliteal vessels, only one study was found based on DS data. A. J. Tindall et al. reported that on examination of 100 patients, high division of the PA was found in 6% of cases [15].

In the course of our work, at the anatomical stage of the study, high bifurcation of the PA was not found in a single case, which corresponds to the data of Ł. Olewnik, et al. [9].

By DS data, the incidence of high bifurcation of the PA was comparable with the data of angiographic studies, but it was fewer than in the work of A. J. Tindall, et al. [15]. It is necessary to emphasize once again that the popliteal fossa region is complex in terms of vascular topography, and the sural arteries, located right in this region, could be mistaken for high bifurcation of the PA. However, the sural arteries always originated from the posterior surface of the PA, while with a high bifurcation of the PA, the ATA originated from the lateral or posterior surface of the artery. Another important practical point may be the fact of the PA deviation towards the lateral side in the distal part of the popliteal fossa, therefore the ultrasound sensor should be positioned slightly outwards the midline at the level of the distal part of the popliteal fossa. Besides, identification of variant anatomy of the PA is facilitated by positioning the ultrasound sensor lateral to the head of fibula (Figure 3).

It is important to note that the identified variants of high origin of the ATA were not aberrant vessels whose principal difference is location between the popliteal muscle and the tibia.

Just a while ago, X-ray contrast phlebography was the standard for assessing the morphofunctional state of the venous system in clinical practice. However, the radiation load and invasiveness of the procedure pushed it into the background, and nowadays it is used only in complex diagnostic cases [4]. The most commonly used method of X-ray contrast phlebography is retrograde phlebography, although the best contrasting of the venous system is achieved when using intraosseous procedure, although this method is most invasive and painful for the patients.

D. J. Quinlan, et al. based on retrograde phlebography data from patients with chronic venous insufficiency,

reported visualization of two vessels at the popliteal fossa in 42% of cases [16]. To note, a complete anatomical picture using this method, can only be obtained with incompetence of both PV trunks.

Modern diagnostics of the lower extremity vein diseases gives preference to noninvasive and minimally invasive examination methods [2, 3]. The main method used in the Russian Federation and widely used abroad is ultrasound examination.

In the study by I. B. Casella, et al. on assessment of the anatomy of the femoropopliteal segment of the deep veins by DS data in patients with varicose disease, duplication of PV was detected only in 2.2% of cases [17]. E. Dona et al. found duplication of PV only in 5% [18].

The data we obtained on topography of the popliteal vein by DS, somewhat differ from both the data of the classic anatomy and the data available in the periodical literature. But it should be taken into account that PV can be formed not only classically in the upper part of the lower leg, but also in the popliteal region [4]. Accordingly, within the borders of the popliteal region, two veins will be present. Interestingly, endovascular surgeons often identify not classic PV anatomy, but just two trunks. E. A. Park, et al., based on CT angiography data, report a high union of tibial vessels into the popliteal vein in 83% of cases [19]. In our work, DS results were confirmed by anatomic preparation, which is known to be a 'gold standard' of vascular system examination permitting to isolate and trace the course of absolutely all vessels. Therefore, data about existence of two PV trunks in the distal part of the popliteal region are important in diagnosing DVT and require a careful assessment of venous patency, which is actually a difficult task, since echogenicity of thrombotic masses is very often similar to that of the surrounding tissues.

An important practical aspect that will facilitate identification of two trunks of the PV by DS, is the maximal relaxation of muscles forming the border of the popliteal region, since ventricumbent position of the patient on examination of the popliteal vessels permits optimal visualization of vessels only in the proximal part of the popliteal region. The part below the knee joint cleft can be clearly traced only to the upper margin of soleus muscle, and in distal direction, visualization is impaired by a large muscular mass and compression of vessels at the level of the tendinous arch, while the popliteal vessels normally divide several centimeters below this margin.

According to the anatomical data, the SSV arises from the superficial venous network of foot and is located in the lower third of the lower leg — along the outer edge of the Achilles tendon, in the middle and upper third of the leg — in the splitting of the crural fascia proper. In the popliteal region, SSV continues into the terminal region — the SPJ, and drains into the PV. However, the classic SPJ occurs in no more than 60% of cases [4, 20].

In our study, classic SPJ was identified in 60% of anatomical preparations and in 63% of cases based on DS data. The entry of the SSV into one of the sural veins was detected in 6% according to anatomical preparation data and in 7.2% according to DS data. In 0.95% of cases, according to DS data, PfVs were detected in the popliteal region, upon that, the SSV did not form SPJ, but passed into the intersaphenous vein. The location of SSV close to the PfV may lead to a false-positive conclusion about the insufficiency or thrombosis of the SSV.

Limitations of this study were the variability of the age and body build of patients, the presence of occlusive lesions of arteries in the amputated lower extremities, the lack of comparative CT angiographic control, and the fact that the study was conducted at a single center. At the same time, the aim of the work was to assess the clinical anatomy of the popliteal region vessels, an important difference between which and normal anatomy is the interpretation of data from the points of view of their clinical significance. That is why the topography data of large vessels in the popliteal region were presented, and occlusive lesions of arteries were a conventional limitation for the preparation. CT angiography is a promising method for studying the vascular system, it is highly suitable for studying the arterial bed, at the same time it has significant limitations for studying the venous system of the lower limbs, so ultrasound remains the gold standard in diagnosing venous diseases of the lower extremities, while anatomical preparation allows for a detailed assessment of the structural and anatomical features of the venous system.

CONCLUSION

The results of the study revealed the following variants of the anatomy of vessels of the popliteal region:

1) two trunks of the popliteal vein below the knee joint cleft in 85.7% to 86% of observations;

2) high bifurcation of the popliteal artery in 1.9% of observations;

3) saphenopopliteal junctions in 60% to 63% of observations;

4) perforator veins of the popliteal region in 0.95% of observations; upon that, the small saphenous vein does not form saphenopopliteal junction.

ADDITIONALLY

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Patient consent. Patient consent. The article uses anonymized clinical data of patients in accordance with their signed informed consents.

Contribution of the authors: *R. E. Kalinin, I. A. Suchkov* — editing; *K. S. Pshennikova* — conducting the ultrasound examination, writing the text; *E. A. Klimentova* — conducting the anatomical preparation, writing the text; *I. N. Shanayev* — conducting anatomical preparation, ultrasound examination, writing the text. The authors confirm the correspondence of their authorship to the ICMJE International Criteria. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

Финансирование. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

Согласие на публикацию. В статье использованы обезличенные клинические данные пациентов в соответствии с подписанными ими добровольным информированным согласием.

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