Letter
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Dissection and Permissible Levels of Proximal Mobilization of Anterior Tibial Vessels During Island Flaps Transfer

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The article presents a discussion with the authors of a previously published article (Zelyanin D.A. et al. Features of the Extraction of the Anterior Tibial Vessels in the Formation of Vascularized Bone Grafts. Traumatology and Orthopedics of Russia. 2022. Vol. 28, No 1. p. 89-99), as well as on the basis of our own topographic and anatomical studies, the information about the details of the topography of the branches of the anterior tibial vascular bundle (ATVB) and the permissible levels of its proximal mobilization during island flaps transfer are justified.
Topographic and anatomical study was performed on 32 non-fixed speciments of the lower extremities for substantiating plastic surgery with island skin flaps isolated on ATVB. The arterial bed of the lower leg was injected with black natural latex Revultex, followed by precision dissection and measurements of all branches of the anterior tibial artery (ATA) with a diameter of 0.3 mm or more using a binocular magnifier with a magnification of 3.3 times. All the studied branches of ATA were identified, the number of which varied from 26 to 49 (on average 38.5–3.2), and 88.7% of them went to the three muscles of the anterior group of the lower leg. At the same time, the average numbers of ATA branches departing in each of the 10% intervals of the length of the lower leg were determined, and the average total values of the cross-sectional area of arterial branches in these intervals were calculated. It was found that from 28% to 39% of the total cross-section of all branches of the ATA are localized in the first and second 10% intervals of the length of the lower leg, which makes it possible to justify the proximal limit of the mobilization of the ATVB. Reasonable criteria for choosing the level of proximal mobilization of the ATVB are: the location of the mobilization border is not higher than the level of the upper 20% of the length of the lower leg, the assignment of this border, at least 6 cm distal from the exit of the anterior tibial vessels into the anterior bone fascial sheath of the lower leg and the preservation of at least four feeding vascular bundles extending from the ATVB to the tibialis anterior muscle (two bundles) and to the extensor digitorum longus muscle (two bundles).

Keywords: pedicled flaps transfer, island flaps, lower leg, anterior tibial vascular bundle, topographical anatomy.

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Особенности выделения и допустимые уровни проксимальной мобилизации передних большеберцовых сосудов при несвободной пересадке кровоснабжаемых комплексов тканей

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В статье представлена дискуссия с авторами ранее опубликованной статьи (Зелянин Д.А. с соавт. Особенности выделения передних большеберцовых сосудов при формировании костных васкуляризированных трансплантатов. Травматология и ортопедия России. 2022. Т. 28, № 1. с. 89-99).
На основании собственных ранее выполненных топографо-анатомических исследований представлены сведения о деталях топографии ветвей переднего большеберцового сосудистого пучка (ПБСП) и обоснованы допустимые уровни его проксимальной мобилизации при несвободной пересадке кровоснабжаемых комплексов тканей. Прикладное топографо-анатомическое исследование выполнено на 32 нефиксированных препаратах нижних конечностей с целью обоснования операций пластики островковыми кожными лоскутами, выделенными на ПБСП. Артериальное русло голени инъецировали черным натуральным латексом Revultex с последующим прецизионным препарированием и измерениями всех ветвей передней большеберцовой артерии (ПБА) диаметром 0,3 мм и более при помощи бинокулярной лупы с увеличением в 3,3 раза. Были установлены все изученные ветви ПБА, число которых варьировало от 26 до 49 (в среднем 38,5–3,2), а 88,7% из них отходили к трем мышцам передней группы голени. При этом были установлены средние количества ветвей ПБА, отходящих в каждом из 10% интервалов длины голени, а также рассчитаны средние суммарные значения площади поперечного сечений артериальных ветвей в указанных интервалах. Было установлено, что от 28% до 39% суммарного поперечного сечения всех ветвей ПБА локализуются в первом и втором 10% интервалах длины голени, что позволяет обосновать проксимальную границу мобилизации ПБСП. Обоснованными критериями при выборе уровня проксимальной мобилизации ПБСК являются: расположение границы мобилизации не выше уровня верхних 20% длины голени, отнесение этой границы как минимум на 6 см дистальнее места выхода передних большеберцовых сосудов в передний костно-фасциальный футляр голени и сохранение не менее четырех питающих сосудистых пучков, отходящих от ПБСП к передней большеберцовой мышце (два пучка) и к длинному разгибателю пальцев (два пучка).

Ключевые слова: несвободная передка кровоснабжаемых комплексов тканей, островковые лоскуты голени, передний большеберцовый сосудистый пучок, топографическая анатомия.

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The article is interesting and informative, as it includes materials of our own applied topographic and anatomical research performed to rationalize complex reconstructive techniques involving transfer of vascularized pedicled bone flaps from the foot and lower leg to the hip area [1]. In our opinion, it is precisely anatomical and clinical approach, the traditions of which were founded in our country by N.I. Pirogov, that is often required for the successful integration of new surgical techniques into clinical practice.

However, the focus of the authors attention was focused on clarifying the features of the deep peroneal nerve branches topography, and the main practical direction of the study is related to the possibilities of preserving these branches during dissection of the vascularized pedicled bone flaps on the anterior tibial vascular bundle. At the same time, the actual applied anatomy of these vessels, well studied in other authors articles [2, 3, 4, 5], it has remained insufficiently discussed, which can lead to mistakes and complications after such operations. Therefore, we decided to draw attention to the results of our earlier topographic and anatomical studies performed to justify techniques with fascio-cutaneus island flaps, which were also dissected on the anterior tibial vessels of the lower leg and transferred in pedicled version to replace extensive and deep defects of soft tissues in the foot or knee joint [5, 6]. More than 30 such surgeries were performed in the period from 1988 to 2000 in the clinic of thermal lesions of the Military Medical Academy named after S.M. Kirov by our teacher — professor S.H. Kichemasov [2, 6, 7]. In our opinion, the results of our previously applied topographic and anatomical studies, the experience of participating in these surgeries and observing the patients afterwards can be a valuable addition to this article and will facilitate for specialists the development of complex of vascularized pedicled bone flaps transferred on the anterior tibial vessels.

First of all, authors would like to draw attention to the results of the applied topographic and anatomical study of the anterior tibial vessels [4], which were summarized in 2004 as part of the A.A. Ostapchenko PhD dissertation. In the course of this study, performed on 32 non-fixed preparations of the lower extremities by precision dissection, the topography of the anterior tibial artery (ATA) and all its branches with a diameter of 0.3 mm and larger was thoroughly studied. At the same time, the arterial bed of the lower leg was pre-injected with black natural latex Revultex, and preparation and measurements were performed using binocular loupes, which provided x3.3 magnification.

According to the results of these studies, several possible variants of dissection and pedicled transfer of fascio-cutaneus island flaps of the lower leg, which were formed in the middle third of the lower leg on the branches of the anterior tibial veins and transferrd on a permanent proximal (option 1) or distal (options 2 and 3) vascular pedicle (Fig. 1). The first variant offered the mobilization of the anterior tibial vessels in the anterior bone-fascial bed of the lower leg using a technique almost identical to that described in the article by D.A. Zelyanin et al. [1]. However, the possible limits of the dissection in the proximal direction of the anterior taibial vascular bundle, accompanied by ligation and intersection of all more distal branches of this main vascular bundle of the lower leg, differed, since they took into account the results of their own topographic and anatomical study, the most important applied details of which are presented below.

On the studied anatomical material, ATA penetrated into the anterior bone-fascial sheath of the lower leg through the gap in the interosseous membrane located below the level of the knee joint gap by an average of 4.8 ± 0.9 cm (variability — from 3.6 to 6.1 cm). Its diameter at this point

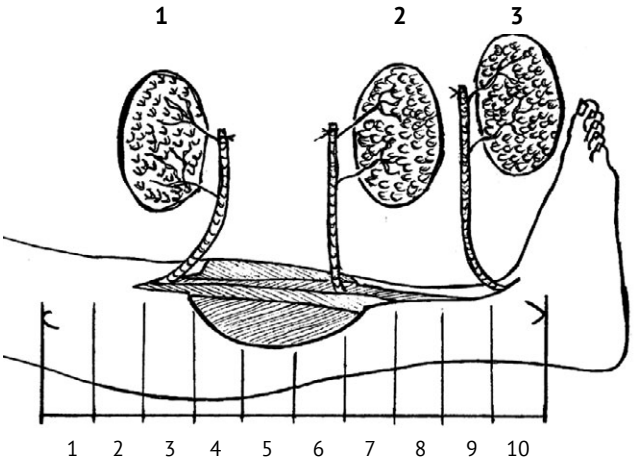

Fig. 1. Scheme of possible options for the formation of island complex skin flaps on the anterior tibial vascular bundle in relation to 10% intervals of the lower leg length

varied from 2.7 to 6.1 mm, and averaged 4.5 ± 0.7 mm. Passing further in the indicated compartment, the ATA formed from 26 to 49 (on average 38.5± 3.2) branches with a diameter of 0.3 mm and larger, most of which (88.7%) were muscular and were directed to the tibialis anterior muscle (TAM), the extensor digitorum longus muscle (EDLM) or the extensor hallucis longus muscle (EHLM).

The performed precision dissection of the branches of the ATA revealed the uneven nature of their distribution on the lower leg, which was important in relation to the studied techniques. Therefore, in the future, an analysis was undertaken of the distribution of the identified arterial branches over 10% intervals of the length of the tibia, which was measured from the tip of the fibula head to the tip of the lateral ankle, varied from 30 to 44 cm on the studied anatomical material, and averaged 35.6 ± 3.2 cm. The results of this analysis are presented in the histogram (Fig. 2).

It was found that in the first 10% interval, ATA gave a relatively small number of branches, and on a number of preparations (27% of observations), the place of its exit into the anterior bone-fascial compartment was generally in the second 10% interval. At the same time, the branches of the first two intervals were directed not only to the muscles of the anterior group of the lower leg, but also to the tibia and fibula and to the knee joint. In the third, fourth, fifth, sixth and seventh 10% intervals, the branches of the ATA departed relatively evenly every 4-11 mm and were directed mainly to the TAM, EDLM or EHLM (Fig. 3). In the eighth, ninth and tenth 10% intervals of lower leg length, ATA branches were statistically significantly less common ($p<0.05$) than in the third-seventh intervals. They supplied blood to the EHLM, the tendons of the anterior group muscles of the lower leg, the periosteum of the tibia and the skin, and also participated in the formation of the ankle network of arterial anastomoses.

The performed precision dissection of the ATA branches showed that the largest of them are located with regular constancy in the first and second 10% intervals of the length of the lower leg. This is confirmed by the calculations of the total cross-section of the branches of the ATA for each of these intervals, which was determined by the formula $S = \varpi(D/2)2$ using the results of measurements of the diameters (D) of the studied arterial branches. The average values of the cross-sectional area of these branches for each of the 10% intervals of the lower leg length are shown in Figure 4.

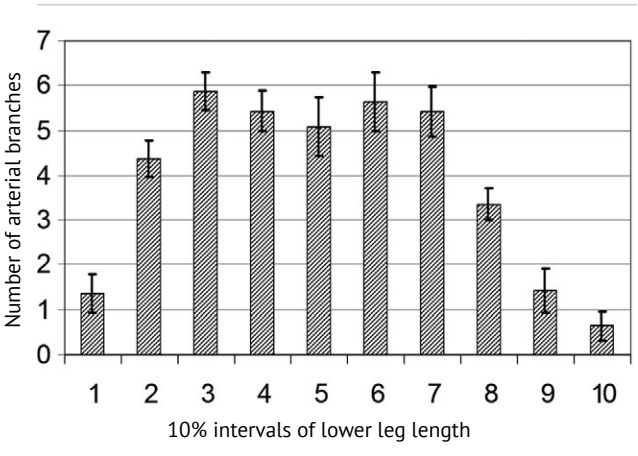

Fig. 2. The anterior tibial artery branches distribution over 10% intervals of the lower leg length (here and further, the height of the column reflects the arithmetic mean value on the interval, and the inaccuracy bars are 95% CI)

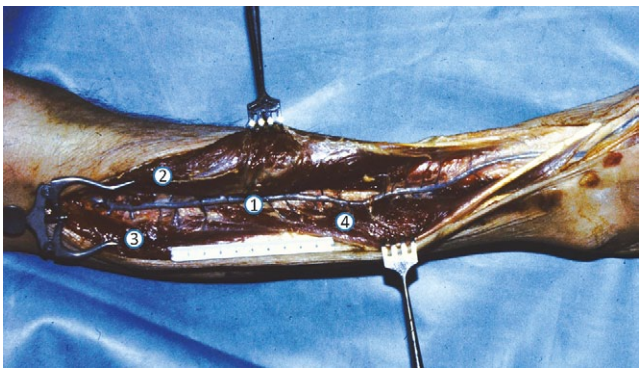

Fig. 3. Branches of the anterior tibial artery to the muscles of the anterior group of the right lower leg; injection of arteries with black latex:
1 — arteria tibialis anterior;
2 — musculus tibialis anterior;
3 — musculus extensor digitorum longus;
4 — musculus extensor hallucis longus

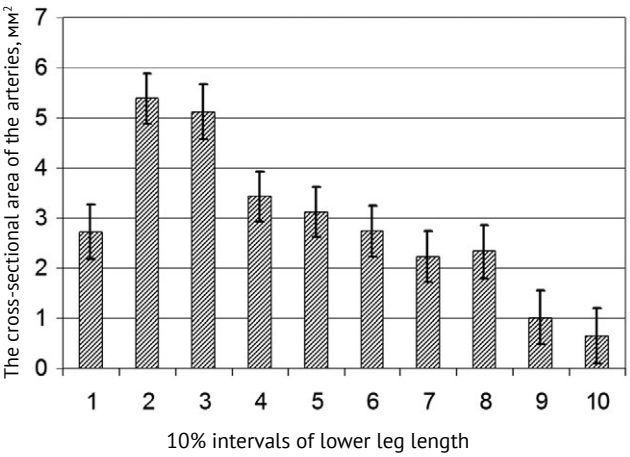

Fig. 4. Histogram of the anterior tibial artery branches average total cross sections distribution over 10% intervals of the lower leg length

At the same time, on the studied preparations, the values of the total cross-section of the branches of the ATA in the first and second intervals ranged from 28% to 39% of this indicator for all branches of the ATA. The predominance of the largest branches of anterior tibialis vessels within the most proximal 20% of the length of the lower leg is also clearly visible on the presented preparation (Fig. 5). In our opinion, this pattern has important practical significance for substantiating the surgical technique.

Taking into account the above, we consider it expedient and justified the level of proximal mobilization of anterior tibialis vessels to the lower edge of the second 10% interval of the lower leg length, within which the largest branches of this

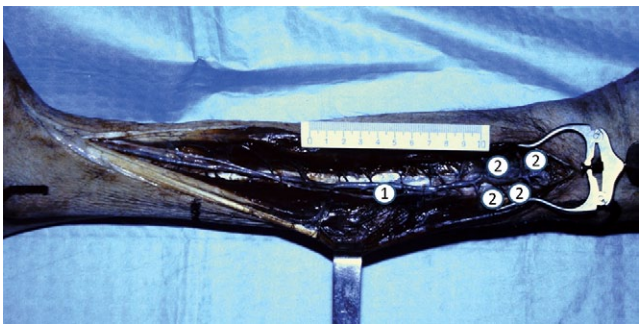

Fig. 5. Major branches of the anterior tibial artery extending in the second 10% interval of the lower leg length; injection of arteries with black latex:
1 — arteria tibialis anterior;
2 — major arterial branch

vascular bundle are localized to TAM and EDLM. Branches to the EHLM in the proximal parts of the lower leg do not depart from the ATA at all, since this muscle begins at the border of the middle and lower thirds of this segment, but its blood supply is also provided by branches of the peroneal artery and veins passing in the anterior intermuscular septum of the lower leg. The point of rotation of the tissue complex isolated on the anterior tibialis vessels will be located with the indicated variant of vascular mobilization 7-8 cm distal to the apex of the fibula head and 9-10 cm below the knee joint gap. A more proximal level of mobilization of anterior tibialis vessels in order to increase the length of the feeding vascular pedicle and the rotation arc of the isolated vascularized bone flaps, in our opinion, is dangerous with undesirable consequences for the function of the two largest muscles of the anterior tibia group - TAM and EDLM due to their ischemic injuries.

In the course of previously performed surgeries of pedicled fascio-cutaneus flaps into the knee joint area, we have always adhered to the rule to stop the proximal mobilization of anterior tibialis vessels at a level of at least 6 cm from the exit of these vessels into the anterior bone-fascial compartment of the lower leg. At the same time, it was monitored that at least two large (more than 3 mm in diameter) feeding vascular bundles extending from the anterior tibialis vessels entered each of the two muscles — TAM and EDLM — more proximally. In our opinion, it is precisely due to this that in none of our clinical observations in the postoperative period there was a significant loss of the function of the extensors of the foot and its fingers, as well as signs of critical ischemia of the muscles of the anterior group of the lower leg.

It should be noted that the authors of this article recommend a more proximal mobilization of the anterior tibialis vessels — up to a level 4 cm distal to the exit of these vessels into the anterior bone-fascial compartment of the lower leg. This gives a gain in the length of the arc of proximal rotation of bone autografts by 4 cm compared to the level recommended by us — 6 cm more distal than the passage of anterior tibialis vessels through the interosseous membrane on the lower leg. However, with a higher mobilization of an-

terior tibialis vessels, it remains unclear which of its branches are preserved and nourish the functionally important muscles of TAM and EDLM. At the same time, the article does not provide data on ischemic lesions and loss of function of the muscles of the anterior group of the lower leg after such operations in the clinic.

I would also like to express my opinion on the issue of maximum preservation of the branches of the deep peroneal nerve during the mobilization of anterior tibialis vessels, which, of course, should be desired. In this regard, the data on the details of the topography of the branches of this nerve, presented in the article, are significant and useful for surgeons.

However, judging by our observations, the largest branches of the deep fibular nerve to the muscles of the anterior group of the lower leg can always be preserved during the mobilization of anterior tibialis vessels, provided with optical magnification (binocular loupes) and microsurgical instruments. Therefore, a more important condition for the preservation of the function of these muscles, in our opinion, is the sufficiency of their blood supply after the mobilization of the anterior tibial vessels. Ischemic damage to these muscles can undoubtedly cause even more significant violations of their contractile function than partial denervation due to the intersection of several small branches of the deep fibular nerve.

In our opinion, the extensive mobilization of anterior tibialis vessels during the surgery, involving the ligation of all its branches in the distal parts of the lower leg for about 25-30 cm (or about 75% of the segment length), seems to be quite dangerous in terms of maintaining adequate blood supply to the muscles of the anterior group of the lower leg. In the course of our previous interventions, the branches of the anterior tibialis vessels were ligated for a maximum of 15-20 cm (or about 50% of the segment length) and mainly only in the middle third of the lower leg. At the same time, pedicled fascio-cataneus flaps on the distal vascular pedicle transfer was most often performed for the reconstruction of severely damaged feet, when maintaining sufficient function of their extension was not a priority. In patients with the femur non-union, the preservation of the function of the muscles of the anterior group of the lower leg can be very important, and serious ischemic disorders in this area can occur many years later due to atherosclerotic lesions of the arterial bed of the lower extremities. Therefore, taking into account the above, all the advantages and disadvantages of complex techniques with transfer of vascularized pedicled bone flaps isolated on a permanent vascular pedicle, including anterior tibialis vessels, should be carefully weighed in the preoperative period, taking into account the individual characteristics of each individual patient.

The authors of this discussion article hope that the applied anatomical information presented in it and the experience of previously performed transfer of vascularized pedicled bone flaps on the anterior tibialis vessels will be useful for surgeons conducting the complex reconstructions, and the level of proximal mobilization of the anterior tibial vessels chosen by them will continue to take into account the criteria justified by us. These, in our opinion, include the location of the proximal border of the mobilization of the anterior tibial vascular bundle not higher than the level of the upper 20% of the length of the tibia (when measured from the tip of the fibula head to the tip of the lateral malleolus), the assignment of this border is at least 6 cm distal to the exit point of the anterior tibial vessels into the anterior bone-fascial compartment of the tibia and the preservation of at least four sufficiently large (with a diameter of more than 3 mm) feeding vascular bundles, extending from the anterior tibialis vessels to the anterior tibial muscle (at least two bundles) and to the extensor digitorum longus muscle (at least two bundles).

DISCLAIMERS

Author contribution

Authors made equal contributions to the study and the publication.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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