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LYMPHATIC DRAINAGE FROM THE SKIN OF THE DISTAL FORELIMB IN KARAKUL SHEEP

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Annotation: *This article highlights the anatomical and physiological characteristics of the lymphatic drainage of the skin in the distal region of the forelimbs of Karakul sheep. The study investigated the location and direction of lymphatic vessels and their connections to the major lymph nodes. Additionally, the drainage characteristics of lymph flow from the skin of the distal region, the functional significance of lymph nodes, and their clinical-practical applications were analyzed. The findings are of significant importance for diagnosing infectious and non-infectious diseases in Karakul sheep and for improving surgical and veterinary-sanitary procedures.*

Keywords: *Karakul sheep, lymphatic system, topographic anatomy, carpal joint, distal limb lymphatic vessels, antebrachial region, livestock policy, breeding work, artificial insemination.*

Аннотация: В данной статье освещаются анатомические и физиологические особенности лимфатического дренажа кожи в дистальной области передних конечностей каракульских овец. В исследовании изучались расположение и направление лимфатических сосудов и их связи с основными лимфатическими узлами. Кроме того, были проанализированы характеристики лимфотока из кожи дистальной области, функциональное значение лимфатических узлов и их клинико-практическое применение. Полученные результаты имеют важное значение для диагностики инфекционных и неинфекционных заболеваний у каракульских овец, а также для совершенствования хирургических и ветеринарно-санитарных процедур.

Ключевые слова: каракульские овцы, лимфатическая система, топографическая анатомия, запястный сустав, лимфатические сосуды дистальных конечностей, предплечевая область, животноводческая политика, селекционная работа, искусственное осеменение.

Meeting the population's demand for livestock products is considered one of the main areas of the state's agrarian policy. The topographic anatomy of the lymphatic system in the forelimbs of Karakul sheep plays an essential role in increasing the number of animals and enhancing livestock production. Therefore, this subject is considered one of the core specialties and serves as an integral part of zooveterinary practice.

In several decrees of the President of the Republic of Uzbekistan and resolutions of the Cabinet of Ministers, it is emphasized that meeting the demand for livestock products is both an economic and political issue.

Modernizing and rapidly developing the livestock sector is a vital part of the overall strategy for the development of the agricultural sector. According to Presidential Resolution PQ-2460 dated December 29, 2015, "On measures for deepening reforms and development of agriculture in 2016-2020," tasks were set to increase the number of cattle to 3.165 million, sheep and goats to 4.281 million, and poultry to 31.2 million by 2020. As a result, during this period, meat production (live weight) was projected to increase by 519 thousand tons, milk by 4.177 million tons, fish by 90 thousand tons, honey by 13.7 thousand tons, and eggs by 4.1 billion.

The "Development Strategy of New Uzbekistan for 2022-2026," outlined in Presidential Decree PF-60 dated January 28, 2022, in its third priority, "Rapid development of the national economy and ensuring high growth rates," includes measures to increase the growth rate of livestock production by 6.2% in 2022. The following targets were set:

- Increasing the number of cattle to 14.5 million, including 4.9 million dairy cows;
- Raising meat production to 2.7 million tons, milk to 12.2 million tons;
- Producing 8.2 billion eggs and 468.4 thousand tons of poultry meat;
- Increasing fish production to 700 thousand tons.

Projects to increase the herd size and productivity of livestock include:

- Implementing 1,868 livestock projects with identified funding sources;
- Breeding new fast-growing beef cattle breeds in Karakalpakstan, Jizzakh, Syrdarya, Navoi, Tashkent, and Khorezm regions, with a target of 100,000 head;
- Increasing the number of trained insemination technicians from 3,000 to 3,200;
- Reclassifying 200 livestock enterprises as "Breeding Category";

- Artificial insemination of 2.4 million cows and heifers (52%) in households;
- Increasing the number of poultry breeding farms to 50;
- Producing 265 million incubation eggs;
- Implementing 306 poultry projects, including modernization and expansion of 7 enterprises and launching 3 cluster projects;
- Distributing 11.1 million poultry to households.

Herd replenishment depends largely on the establishment of an efficient organizational system for the use of male and female breeding animals, and on planning zooveterinary measures according to regional conditions and applied technological methods. Correct organization of these tasks requires specialists to have deep knowledge and practical skills in the subject of "Obstetrics and Artificial Insemination of Animals."

Students specializing in animal science (zooinjineering) must be knowledgeable about the prevalence, causes, course, diagnosis, differential diagnosis, prevention, and effective treatment of various obstetric and gynecological diseases in animals. They must also be competent in organizing measures aimed at herd replenishment, prevention and elimination of infertility. This requires specialists to be well-versed in obstetrics, artificial insemination, veterinary gynecology, and animal reproductive biotechnology.

Karakul sheep farming is considered a key sector for meeting the population's demand for products such as meat, wool, and astrakhan pelts. Therefore, Karakul sheep as biological models are of scientific and practical interest in many disciplines. Over the last decade, the veterinary field has conducted comprehensive studies on various systems of Karakul sheep, including the lymphatic system, which, despite being less studied, performs essential biological functions in both animals and humans.

To identify lymphatic vessels in the skin of the distal region of the forelimb in Karakul sheep, we used a method involving the injection of a contrasting agent consisting of a water solution of black ink and 10–15% collargol. As shown in Figure 1, the contrast agent was injected in a chessboard pattern, with injection points spaced 1.5 cm apart. This technique enables the identification of a large number of lymphatic vessels. To facilitate the anatomical-topographic recording of the lymphatic vessels, the examined area was divided as follows: finger-palm region, carpal (bracelet) region, forearm (wrist-elbow) region, and elbow region.

1. Lymphatic drainage pathways from the finger and palm skin

This region is bordered as follows: the lower boundary begins at the palmar surface of the hoof, and the upper boundary is a horizontal line passing through the proximal epiphysis of the metacarpal bone.

From the skin of the hoof wall and outer surface, 6–8 small lymphatic vessels emerge (Figure 4-1). Around the sesamoid bones, these vessels merge into 2–4 main lymphatic trunks.

Figure 1. Formation of lymphatic vessels in the skin. Site of contrast agent injection.

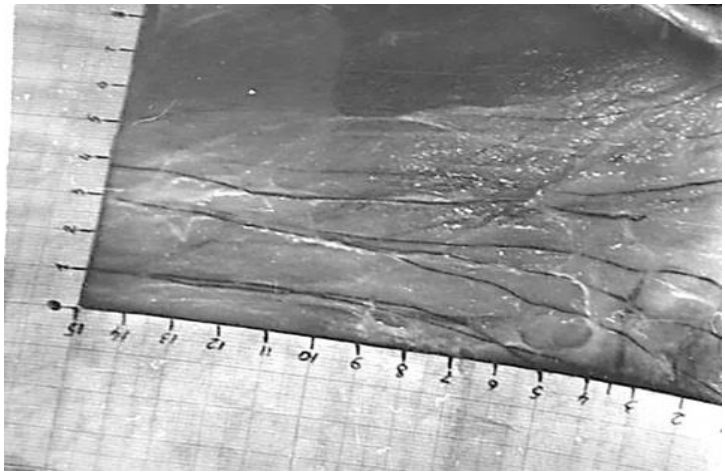


Figure 2. Formation of the main (trunk) lymphatic vessels of the skin.

1–2 of the lymphatic vessels are directed toward the dorsal surface of the digit, while the remaining 1–2 vessels head toward the lateral (or medial) surface of the digit.

The first pathway drains into a lymphatic collector running along the lateral and medial palmar arteries and veins of the digit.

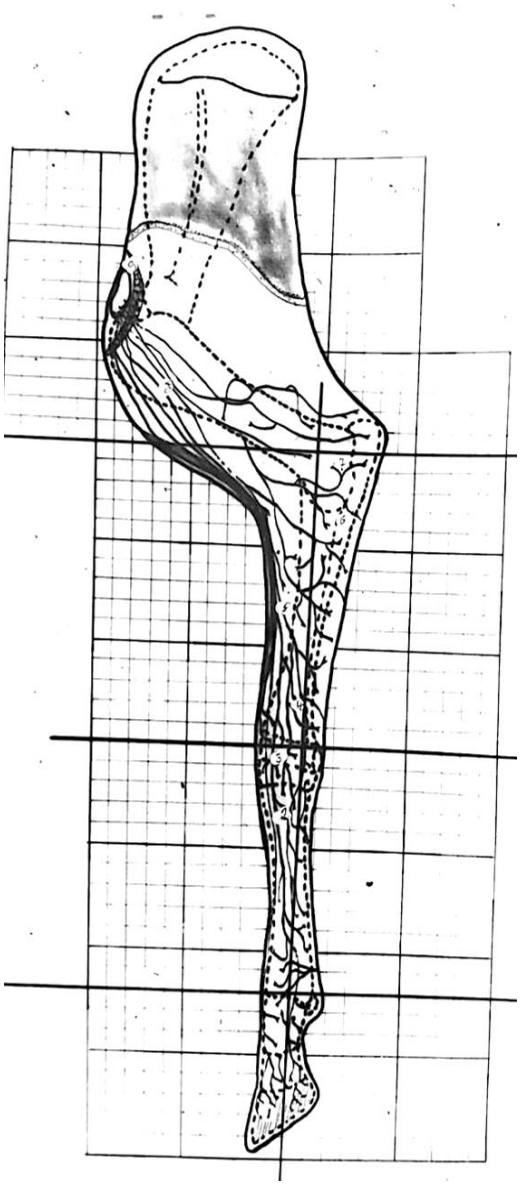
The second pathway drains into a lymphatic collector associated with the common dorsal artery and vein of the digit.

From the interdigital skin base over the sesamoid bone and from the wall of the digit, 4–6 small lymphatic vessels emerge on its outer surface (Figure 4-1). After passing the coronary band, these vessels merge to form 2–3 branching lymphatic vessels, which travel along the blood vessels.

At the level of the second phalangeal joint, they drain into a lymphatic collector accompanying the third dorsal digital artery and vein on the lateral side, then head proximally. From the skin of the coronary band, 2–3 lymphatic vessels arise and travel dorsally and latero-palmarly.

In the region of the second phalangeal joint, they drain into the main lymphatic vessels and collectors that follow the common dorsal artery and veins, and the 4 lateral and 3 medial palmar arteries and veins of the digit.

The extra-organ lymphatic vessels from the dermal base of the hoof in the second digit form 2–4 lymphatic plexuses (clusters) (Figure 4-1). Each plexus is formed by 1–2 branching lymphatic vessels.



The lymphatic vessels emerging from the plexus join and move proximally, lying between the laminar layer of the dermis and the wall of the hoof bone. Then, 1–2 vessels enter a lymphatic collector located along the path of the interdigital arterial arch.
The remaining 1–2 vessels travel proximally and drain into a lymphatic collector running along the third dorsal digital artery and vein, located near the proximal epiphysis of the pastern bone.

The lymph from this region flows into the superficial lymph nodes of the forelimb.

In the third digit, the lymphatic system of the hoof sole dermis differs from that of the fourth digit in being more developed.

From the formed lymphatic plexuses, 3–5 branching lymphatic vessels emerge (Figure 4-1). Of these, 2–3 travel proximally, reaching the middle part of the pastern bone, where they merge and redirect dorsally.

The remaining 1–2 lymphatic vessels are directed palmarly and merge with lymphatic vessels coming from the soft tissues of the hoof sole in the middle region of the pastern bone. The resulting main lymphatic vessels then continue in a proximal direction.

Figure 3. Lymphatic drainage from the skin of the forelimb — lateral view.

1. Lymphatic vessels in the digital region
2. Lymphatic vessels in the palmar region
3. Lymphatic vessels in the carpal (bracelet) joint region
4. Lymphatic vessels in the lower part of the forearm
5. Lymphatic vessels in the middle part of the forearm
6. Lymphatic vessels in the upper part of the forearm
7. Lymphatic vessels in the elbow region
8. Lateral bundle of lymphatic vessels
9. Superficial cervical lymph node

Additional anatomical description:

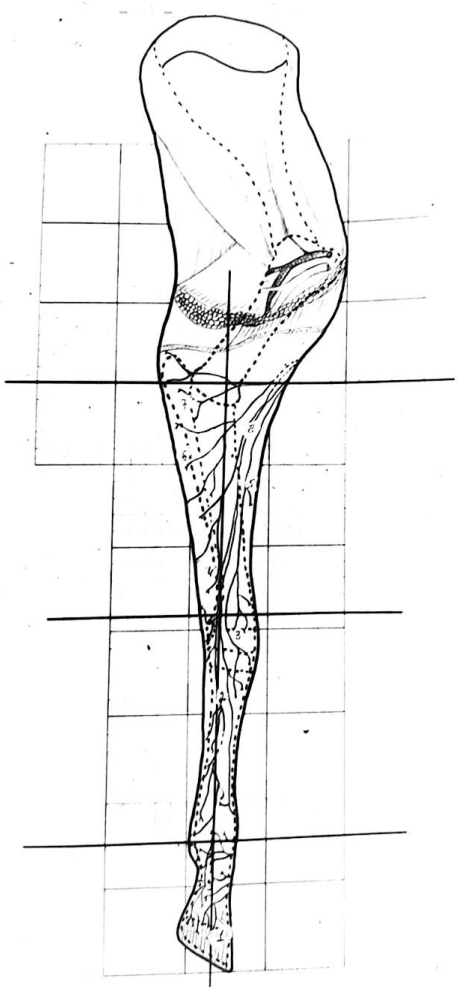
In some cases, it was observed that lymphatic vessels penetrate the deep fascia in the area of the middle part of the pastern bone, and then drain into lymphatic collectors running along the palmar arteries and veins of the digits.

In such cases, the lymph flows to the axillary lymph node.

From the lateral skin surface of the phalanges of the second and first digits, 5–7 small lymphatic vessels emerge. These vessels merge to form 2–4 main (trunk) lymphatic vessels.

Of these:

1–2 vessels travel toward the dorsal surface of the digits and then proximally toward the palm, following the dorsal arteries and veins of the digits.



The other 1–2 vessels are directed toward the plantar (palmar) surface, where they pierce the fascia and drain into the lymphatic collector that runs along the 4 lateral palmar arteries and veins of the digits.

From the medial surface of the phalanges of the first and second digits, 6–8 small lymphatic vessels emerge (Figure 5-1), which merge to form 3–4 main lymphatic vessels.

Of these:

2–3 vessels are directed toward the dorsal surface of the digits and then toward the palm, following the dorsal arteries and veins of the digits.

The remaining 1–2 vessels are directed toward the palmar surface (Figure 5) where they penetrate the fascia and drain into the lymphatic collector running along the three medial palmar arteries and veins.

Figure 4. Lymphatic drainage from the medial surface of the forelimb skin. Image copy from coordinate dioptrography.

1. Lymphatic vessels of the digital region. 2. Lymphatic vessels of the palmar region. 3. Lymphatic vessels of the carpal (bracelet) joint region. 4. Lymphatic vessels of the lower forearm. 5. Lymphatic vessels of the middle forearm. 6. Lymphatic vessels of the upper forearm. 7. Lymphatic vessels of the elbow region. 8. Medial bundle of lymphatic vessels.From the palmar skin surface of the first and second phalanges, 6–8 small extra-organ lymphatic vessels emerge (Figure 6-1). These form 3–4 branching vessels, directed toward the latero-medial surface, and drain into the lymphatic vessels in that region.

In the rudimentary regions of the digits, lymphatic vessels merge to form 2–3 main lymphatic trunks, which do not follow the blood vessels, but rather travel independently in a proximal direction.

From the interdigital skin, 2–3 lymphatic vessels emerge and run proximally toward the dorsal surface of the pastern bone, then to the dorsal surface of the metacarpal bone, and finally drain into the main dorsal lymphatic collector, which accompanies the common dorsal arteries and veins.

In this case, lymph drains into the superficial cervical lymph node. Thus, the lymphatic system in the digital region of Karakul sheep is anatomically and topographically complex. We believe this is due to the adaptation of Karakul sheep to various ecological zones of the Republic.

Since the main weight load is placed on the distal limb, this has led to a complex angioarchitecture (arterial, venous, and lymphatic) in the digital region.From the findings, it is evident that lymph from the digits drains via both superficial and deep lymphatic vessels, reaching the superficial and axillary lymph nodes.From the lateral skin surface of the palmar region, 5–7 small lymphatic vessels arise (Figure 4-2). These merge to form 3–5 branching lymphatic vessels, of which:

- 1–2 vessels are directed toward the dorsal surface, where they merge with lymphatic vessels coming from the digital region,
- The remaining 2–3 vessels run proximally toward the carpal (bracelet) joint region.

Figure 6. In this case, lymph drains into the superficial lymph node of the joint.

From the medial skin surface of the palmar region, 6–8 small lymphatic vessels emerge (Figure 5-2), and merge to form 4–6 branching lymphatic vessels. Of these:

- 1–2 vessels run mediolaterally toward the dorsal side, where they join vessels from the digits and lateral surface,
- The remaining 1–3 vessels travel proximally into the carpal joint region.

Lymph drains into the superficial cervical lymph node. From the palmar skin surface of the palm, 8–10 small lymphatic vessels arise (Figure 6-8).

- 4–5 of these are directed toward the lateral surface of the palm and drain into the lymphatic vessels of that area,
- The other 4–5 vessels are directed toward the medial surface, and as previously described, drain into the medial lymphatic vessels.

In both cases, lymph ultimately drains into the superficial cervical lymph node. Lymphatic drainage from the skin of the carpal (bracelet) joint region

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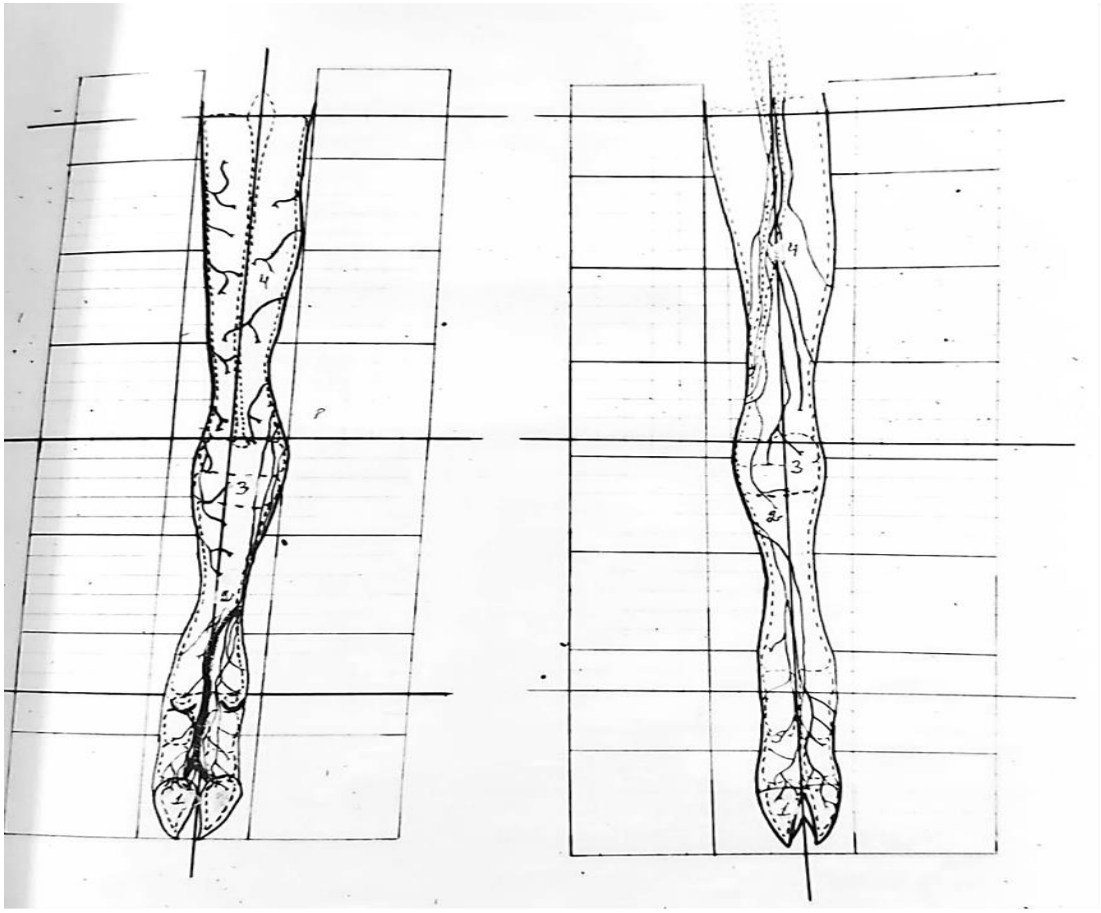


Figure 5. Lymphatic drainage from the skin of the forelimb (dorsal and palmar surfaces)

1. Lymphatic vessels of the digital region.
2. Lymphatic vessels of the palmar (metacarpal) region.

3. Lymphatic vessels of the carpal (bracelet joint) region.
4. Lymphatic vessels of the forearm region.
5. Superficial cervical lymph node.

In Karakul sheep, the carpal (bracelet) joint region is defined by the following anatomical boundaries:

- The lower boundary corresponds to a horizontal line drawn along the proximal epiphysis of the metacarpal bone.
- The upper boundary lies at the level of the upper end of the accessory bone of the carpal joint.

From the lateral-palmar and lateral surfaces of the skin of the carpal joint region, 1 to 4 small lymphatic vessels emerge from the site of contrast medium injection (Figure 4-3; Figure 1-2). These vessels anastomose with each other and form 3–5 relatively large, branching lymphatic vessels running upward over the fascia. As they ascend, the vessels merge progressively, forming 2 to 4 main lymphatic trunks (measuring approximately 0.2–0.4 mm in diameter), which run dorsally (Figure 2) and contribute to the formation of the lateral lymphatic bundle of the antebrachial (forearm) region.

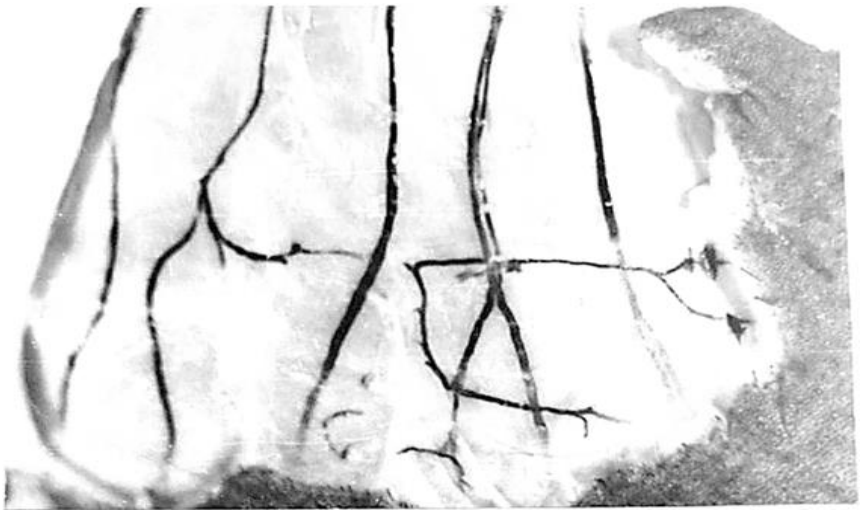


Figure 6. Main lymphatic vessels in the forearm region.

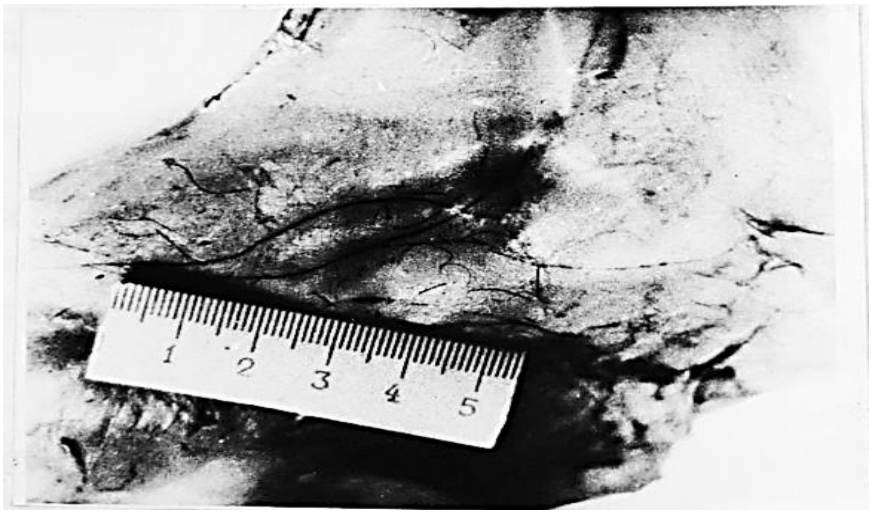


Figure 7. Lymphatic vessels in the elbow region

Cases of the main lymphatic vessels of the described areas passing independently until they reach the regional lymph nodes have also been rarely noted (reports 8, 19).

From the medio-palmar (Fig. 6-3) and medial surfaces of the skin in the area of the wrist joint, 1-2 small lymphatic vessels emerge from the injection site (Fig. 2), located over the fascia (Fig. 5-3). On the latero-palmar surface, 2-4 branching vessels directed from bottom to top begin. Along their course, these vessels anastomose with each other, forming 1-2 main lymphatic vessels, which run along the subcutaneous vein of the forearm-elbow, heading towards the flexor surface of the elbow joint and participate in forming the medial lymphatic trunk.

From the dorsal surface of the wrist joint, 1-2 small lymphatic vessels emerge from the injection site (Fig. 6-3); they anastomose with each other and form 2-4 large branching vessels located over the fascia and directed from bottom to top. These vessels join with each other along their path, forming 1-3 main lymphatic vessels. The formation of these vessels also involves lymphatic vessels coming from the fingers and palm areas. Then, running along the subcutaneous vein of the forearm-elbow, they form the dorsal lymphatic trunk. In the area of the flexor surface of the elbow joint, they pass to the dorso-lateral surface of the shoulder and head towards the superficial cervical lymph node (Fig. 4-9; Fig. 10-1).

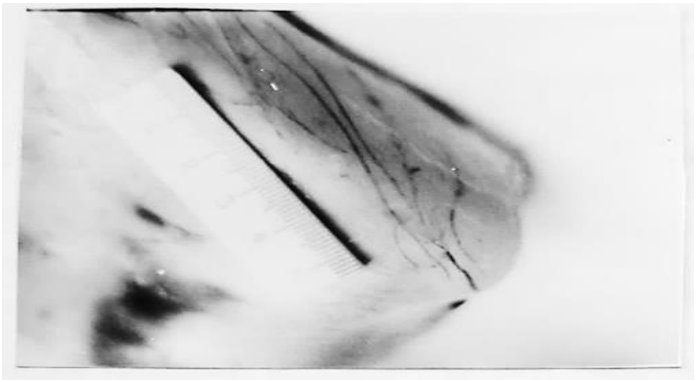


Figure 8. Dorsomedial lymphatic trunk.

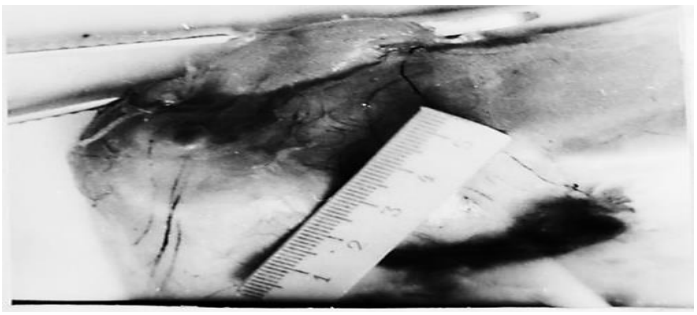


Figure 9. Regional lymph node of the forelimb.
I – Superficial cervical lymph node
II – Accessory lymph node

Lymph flows from the skin of the forearm-elbow region.

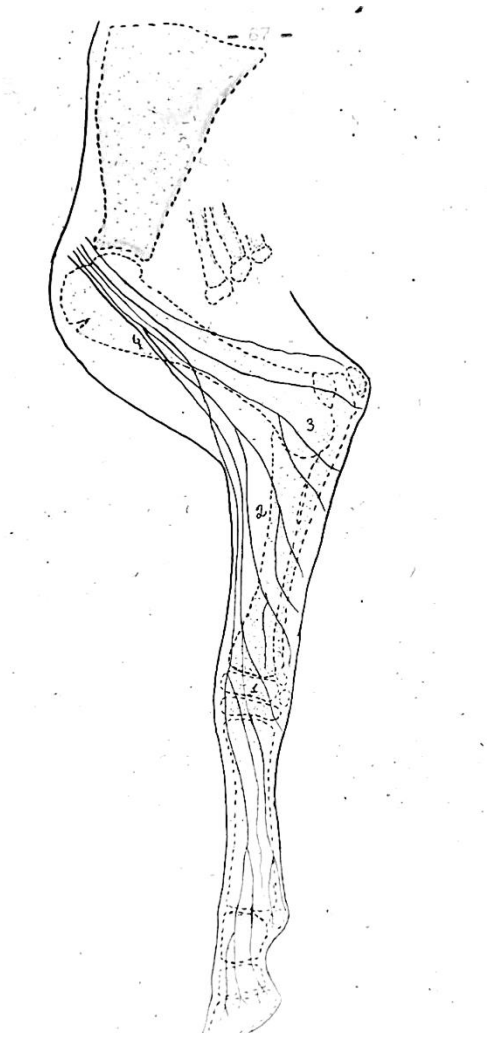
It should be noted that the lymphatic vessels of the lateral and medial surfaces of the skin of the wrist joint area are formed according to the skin’s stretching and folding, while on the dorsal surface of the joint, they are positioned relative to the longitudinal axis of the joint. In Karakul sheep, the forearm-elbow region is bounded as follows: the upper boundary runs along a horizontal line passing through the proximal epiphysis of the radius bone, while the lower boundary corresponds to the upper edge of the wrist joint. For convenience in describing the lymphatic outflow pathways from the skin of the forearm-elbow region, it is divided into three parts: upper, middle, and lower. This conditional division is considered when describing the lymphatic vessels on the lateral, medial,

palmar, and dorsal surfaces. From the lower part of the forearm-elbow skin, 1-2 small lymphatic vessels emerge from the injection sites on the latero-palmar lateral and latero-dorsal surfaces (Fig. 4-; Fig. 12-g). These vessels anastomose and form 2-4 branching lymphatic vessels located over the fascia and directed obliquely upwards (Fig. 7). Along their course, these vessels join to form 1-2 main lymphatic vessels that participate in forming the lateral lymphatic trunk. These vessels receive lymphatic tributaries from the fingers, palm, and wrist joint areas. In the upper part of the forearm-elbow region, these vessels penetrate the superficial fascia and deep fascia and lie between the fascia layers. From here, lymph flows to the superficial cervical lymph node (Fig. 10-; Fig. 4-9). From the middle part of the forearm-elbow skin, 2-3 small lymphatic vessels emerge from the injection sites on the latero-palmar, lateral, and latero-dorsal surfaces (Fig. 4-5). These vessels anastomose with each other and give rise to 3-5 branching vessels measuring 0.1–0.3 mm, directed caudo-dorso-proximally. In this area, the vessels lie over the fascia. While moving through different parts of the upper forearm-elbow region, these vessels join to form 2-4 main lymphatic vessels that participate in forming the lateral lymphatic trunk (Fig. 7). These vessels pierce the superficial fascia and deep fascia and lie either between or above the fascia until they drain into the lymph node (report 25). At the point where lymphatic vessels enter the superficial cervical lymph node of the neck, they pierce the fascia and the shoulder-head muscle and pass under the fascia. This section measures approximately 1.5–2 cm (Fig. 4-9). In one instance (report 30), a main lymphatic vessel from the middle part of the forearm was noted to enter the accessory prescapular lymph node (Fig. 10-2). From the upper part of the forearm-elbow skin, 2-3 small lymphatic vessels emerge from the injection sites on the latero-palmar, lateral, and latero-dorsal surfaces (Fig. 4-6). They immediately anastomose and form 2-3 branching lymphatic vessels lying over the fascia, directed caudo-cranially. These branching vessels join and form 1-2 main lymphatic vessels participating in the formation of the lateral lymphatic trunk. The indicated main lymphatic vessels run toward the regional lymph node, penetrate the double-layered superficial fascia in the lower shoulder area, and lie under the fascia. At the point of entry into the superficial cervical lymph node, the vessels pierce the double-layered fascia and the shoulder-head muscle, lying beneath the fascia.

Lower part of the forearm-elbow skin: From the injection sites on the medio-palmar, mesial, and medio-dorsal surfaces, 1–2 small lymphatic vessels emerge (Fig. 5-4). These vessels immediately anastomose and form 2–3 branching lymphatic vessels located over the fascia and directed medio-dorsally. Along their path, they unite and form 1–2 main lymphatic vessels running toward the flexor surface of the elbow joint. These vessels pass to the dorso-lateral surface of the shoulder and participate in the formation of the lateral lymphatic trunk. Lymph then flows into the superficial cervical lymph node (Fig. 4-9).

Middle part of the forearm-elbow skin: From the injection sites on the aforementioned surfaces, 1–3 small lymphatic vessels emerge (Fig. 5-5), which anastomose to form 3–5 branching lymphatic vessels sized 0.1–0.2 mm located under the fascia and directed medio-dorsally. These vessels unite along their course and form 2–3 main lymphatic vessels running toward the flexor surface of the elbow joint. Along the medio-dorsal surface, they pass to the dorso-lateral surface of the shoulder and form the lateral lymphatic trunk before entering the regional lymph node.

Upper part of the for earm-elbow skin: From the injection sites on the medio-palmar, medial, and medio-dorsal surfaces, 1–2 small lymphatic vessels emerge (Fig. 5-6). These vessels anastomose to form branching lymphatic vessels located over the fascia. They unite along their course and form 1–2 main lymphatic vessels (Fig. 5-8) that curve like an “S” along the flexor surface of the



elbow joint, pass to the dorso-lateral surface of the shoulder, and proceed toward the superficial cervical lymph node. As these lymphatic vessels travel to the node, they are located beneath, within, and above the fascia, similarly to the vessels on the lateral surface.

Figure 10. Lymphatic outflow pathways from the skin of the forelimb. Limiorenttenotramma tracing image.

1. Lymphatic vessels in the wrist joint region
2. Lymphatic vessels in the forearm region
3. Lymphatic vessels in the elbow region
4. Main lymphatic vessels

It is also observed that main lymphatic vessels may be located only over the fascia until they enter the lymph node (reports 9, 25). The upper boundary of the elbow region corresponds to a horizontal line passing through the upper end of the humeral trochlea, and the lower boundary corresponds to a horizontal line passing through the proximal epiphysis of the radius.

From the latero-palmar and lateral surfaces of the elbow skin, 2 small lymphatic vessels emerge from the contrast injection sites (Fig. 4-7; Fig. 8). These vessels anastomose to form 2–3 branching lymphatic vessels located over the fascia and directed latero-dorsally. Along their path, they unite to form 1–2 main lymphatic vessels that participate in the formation of the lateral lymphatic trunk (Fig. 12-14). In the mid-shoulder area, one or rarely two main lymphatic vessels perforate the superficial fascia and lie between the fascia layers, running toward the superficial cervical lymph node (Fig. 4-9).

From the medial and medio-palmar surfaces of the elbow skin, 1–2 small lymphatic vessels emerge from the injection sites (Fig. 5-7; Fig. 12-), which anastomose and form 2–3 branching lymphatic vessels directed caudo-cranially toward the flexor surface of the elbow joint. Later, they unite and form 1–2 main lymphatic vessels that participate in the formation of the medial lymphatic trunk (Fig. 12-4; Fig. 9).

Conclusion:

The conducted research identified the morphological and physiological features of lymphatic outflow from the skin of the distal forelimb in Karakul sheep. The study explored the location, structure, and direction of lymphatic flow in this area. It was found that lymphatic flow in the distal forelimb primarily occurs through superficial lymphatic vessels directed toward peripheral lymph nodes. The intensity of lymph flow varies depending on the animal’s age, physical activity, and environmental factors. The obtained data are important for assessing the health of Karakul sheep, early detection of diseases, and prevention of lymphatic system-related pathologies. These results serve as a scientific basis for practical applications in veterinary medicine.

The lymphatic vessels curve in an “S” shape along the flexor surface of the elbow joint, pass to the dorsal surface of the shoulder, pierce the superficial fascia, and lie between the fascia layers.

Before entering the superficial cervical lymph node, they pierce the fascia and the shoulder-head muscle and lie beneath the fascia. Thus, the lymph from the skin of the wrist, forearm-elbow, and elbow joint areas of Karakul sheep drains into the main lymphatic vessel located over, within, and beneath the fascia. The regional lymph node for lymphatic vessels of this area is the superficial cervical lymph node.

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