

## PLANTAR LYMPHATIC NETWORK

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### ABSTRACT

*Anatomical descriptions of the lymphatic system of the foot remain imprecise. In the present report, we aim to elucidate the anatomical lymphatic plantar network in order to improve current clinical practice on the foot. Lower limbs from a total of 25 human cadavers, 4 amputated limbs, and 8 term fetuses were studied. All cadavers were subjected to injection procedures, formalized, immersed in a solution of hydrogen peroxide, and finally dissected. On 6 of the fetal samples, the diaphanization Spatelholz technique was followed. The superficial lymphatic network of the sole is morphologically divided into three plexuses: anterior, medium, and posterior, with the medium differing from the rest. The anterior plexus presents lymphatic vessels forming scarce polygonal figures of considerable size that converge towards the medial edge to constitute ascending trunks. The middle plexus is characterized by the presence of transverse interconnected trunks that extend from one edge to the other of the sole. The posterior plexus presents polygonal figures of smaller size and greater number than the anterior plexus and forms ascending trunks that are directed to the dorsal surface of the foot. These observations demonstrate that the plantar lymphatic network display important*

*differences among the caliber of the lymphatic vessels as well as in the communication and morphological shape of their plexus. Finally, a comparative distribution and organization between the lymphatic and the venous networks was also examined.*

**Keywords:** lymphatic system, plantar lymphatic network, venous network, post-mortem injections

The first detailed iconographic illustrations of the superficial lymphatic system of the sole should be recognized in the studies of Sappey MPC (1874 and 1888) (1). His work became the canonical bibliography on the subject representing the lymphatic network as small vessels emerging from the inner and outer edges of the foot. In fact, the lymphatic trunks that are initiated from the inner edge of the foot are characterized in their origin by numerous collectors leaving from the plantar network that then emerge as anterior, medium, and posterior trunks.

The anterior, in numbers of four to five minor trunks, are directed obliquely towards the upper and posterior region of the foot, and then join those that run on the dorsal side. The medium trunks are of larger size and are arranged in number of approximately ten that pass vertically in front of the internal malleo-

lus. Unlike the medium, the posterior trunks display a smaller caliber and three of those are recognized to arise from the inner part of the heel to then occupy the space that separates the inner malleolus from the Achilles tendon.

The trunks that depart from the outer edge, a little less numerous than the preceding ones, are aligned according to their relationship with respect to the malleolus in: anterior, submalleolars, and posterior. The anterior trunks, the quantity of which is difficult to establish, come down generally to two or three. They accompany the trajectory of the external collateral trunks of the little toe and are added immediately to those trunks of the dorsal face. The submalleolares are characterized at their point of origin by numerous long branches the volume of which does not overcome that of the adjacent trunks.

Over their trajectory, submalleolares trunks cross obliquely the external malleolus and run through the posterior outside part of the leg. The posterior trunks, in number of approximately ten, are characterized by their caliber. They arise from the outer and posterior part of the heel skin and run along the space between the outer malleolus and the Achilles tendon. The above mentioned go together with the minor saphenous vein to reach the nodes of the popliteal hollow where the remaining trunks of the foot run together with the major saphenous vein to reach the inguinal nodes (1).

Both these images as published by Poirier and Charpy (2) represent a concept of the lymphatic network distinct from that proposed in our current study. It is worthy to remark that those previous investigations employed mercury through direct injections as a research technique and the aforementioned images probably overestimate the size of the lymphatic network (2). In the study of human lymphatics by Rouviere (3), more accurate images of the lymphatic network of the sole of the foot are presented. Moreover, it is suggested that the network of the sole is in direct connection from the inner edge with the dorsum

of the foot and more precisely with the origin of the lymphatic internal saphenous (3,4).

In the present study, by employing different injection techniques on cadaveric material we aimed to elucidate the lymphatic network of the sole to assess its importance in vascular rehabilitation (5). In addition, a comparative study upon the distribution and vessel morphology between the lymphatic and the venous networks is also presented (6).

#### *MATERIAL AND METHODS*

A total of 70 cadaveric lower limbs were examined comprising 25 adults (both sexes and ages between 50-80 years) and 8 fetuses between 35 and 40 weeks of development with an additional 4 adult lower limbs obtained from surgical amputations. All cadaver parts were subjected to injection procedures with a modified Gerota mass. The original Gerota mass compound consisted of 0.2% of Prussian blue as a dye and 1.5% sulphuric ether as a dilator of the lymphatic capillaries with both substances mixed in 0.3% of turpentine oil as diluent. Our modification involved the exclusion of the sulphuric ether in the Gerota mass compound and added heating of the anatomical specimen with 100 Watt lamp for 10 minutes at 20 cm distance immediately prior to the injection. Following heating, a dental carpule syringe was employed to inject 1ml each of modified Gerota into 4 to 5 contiguous lineal sectors of the peripheral region of the sole (*Fig. 1*). The injected lower limbs were fixed by immersion for 7 days in an aqueous solution containing 5% formalin v/v, then cleared with 100% hydrogen peroxide for 24 hr.

On 6 of the fetal limbs, a diaphanization procedure under the Spatelholz technique was followed. Briefly, in order to visualize the small lymphatic vessels, the refraction index of the tissue was changed by dehydrating the material with a series of increasing grades of alcohol and finally immersing the dehydrated piece in xylene (*Fig. 2*). In order to compare



*Fig. 1. Modified Gerota's mass injected at several points in a line on peripheral surface of the sole. Approximately 1ml of the solution was injected in each point.*



*Fig. 2. Superficial lymphatic vessels of the dorsal part of the foot visualized by a diaphanization procedure in a fetal foot.*

the distribution, extension, and morphological features of lymphatic and venous networks, 25 cadaveric limbs were injected with a solution of natural acrylic pigmented latex diluted in distilled water. An afferent vessel of the marginal internal vein at the distal portion of the leg was cannulated following the technical procedures previously reported for venous visualization (6).

Preserved anatomical pieces were carefully dissected, anatomical structures identified, and photo documented by employing an Olympus Stylus 1 12Mp 10.7 x 3" digital camera. The cadaveric material employed in the present study belongs to the III Chair of Anatomy, School of Medicine, University of Buenos Aires.

## RESULTS

After a careful dissection and interpretation of the lymphatic and venous vessels located in the superficial sole of the foot, we observed that both anatomical pathways present a similar arrangement with three plexuses (anterior, middle, and posterior) in the form of a network. Moreover, the lymphatic network demonstrated a smaller number of vessels of smaller caliber with less intercommunications compared to the venous network (*Fig. 3*).

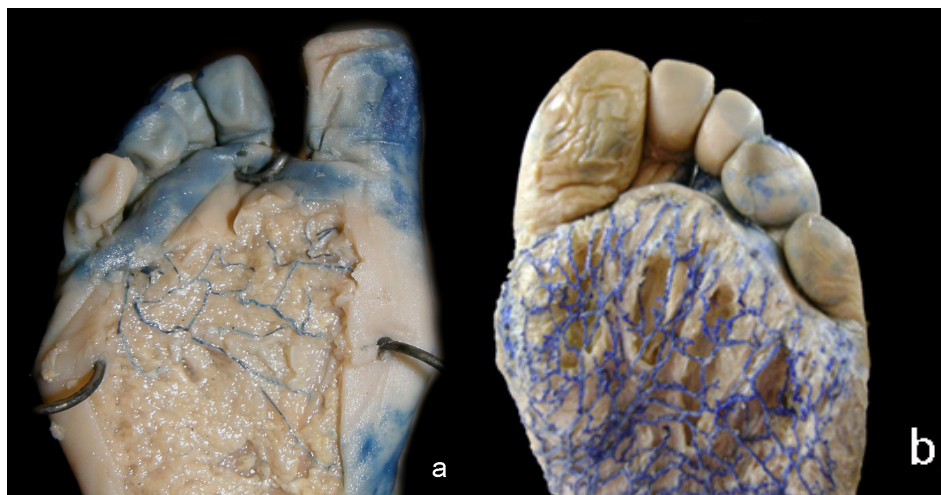
In the anterior region of the sole, whereas the lymphatic plexus exhibited the presence of polygonal figures that are of greater size but fewer in number, the corresponding venous plexus consisted of better defined figures of reduced size (*Fig. 4*).

The middle lymphatic plexus had transverse trunks in almost extensions with scarce communications between them. The venous plexus was characterized by the presence of polygonal figures in the middle region, which then continued with ascending trunks toward both edges of the foot (*Fig. 5*).

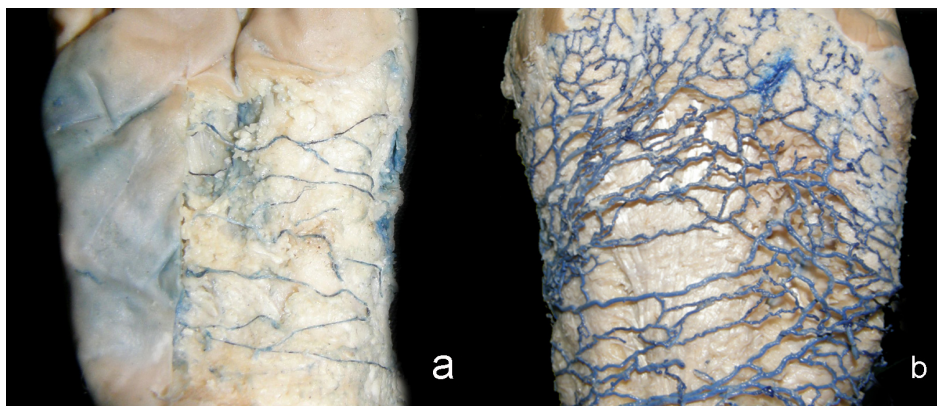
At the level of the heel, the posterior lymphatic plexus had a polygonal disposition and acquired small figures of transverse orientation with regard to the longitudinal axis of the foot. In the veins of the sole, vessels



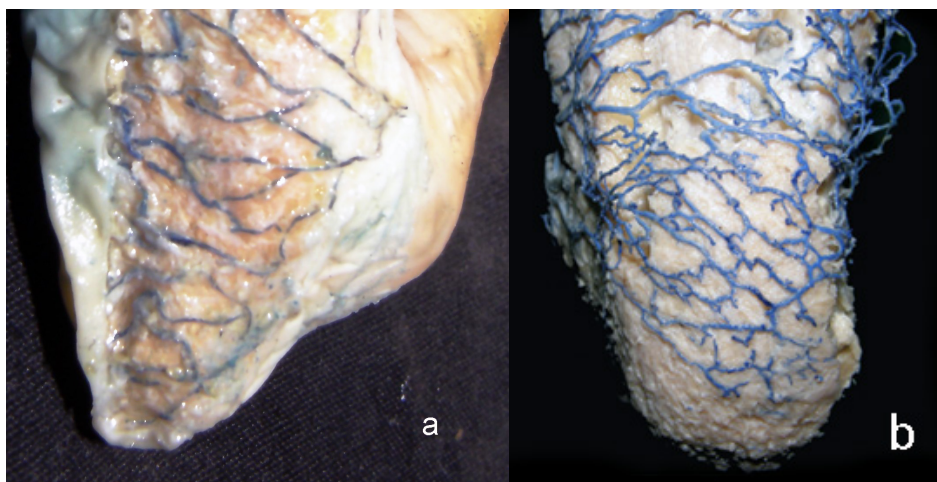
*Fig. 3. Enlarged photographs of anatomical dissections of the sole showing the superficial a) lymphatic and b) venous networks.*



*Fig. 4. Amplified photographs showing the anterior a) lymphatic and b) venous plexuses. The lymphatic vessels are arranged in scarce polygonal figures of considerable size that converge towards the medial border constituting ascending trunks. The venous vessels are settled in small irregular polygonal figures draining to the dorsal region of the foot through the interdigital spaces.*



*Fig. 5. Enlarged photograph displaying a) the middle lymphatic plexus and b) the medial venous plexus. The lymphatic plexus in this region is characterized by the presence of lymphatic trunks that are transversely intercommunicated and prolonged from one edge to the other of the sole. The venous network is molded by well-defined polygonal structures (medial-lateral region) or quadrilateral interrelated structures (medial-medial region)*



*Fig. 6. Enlarged photographs of the heel demonstrating the posterior a) lymphatic and b) venous plexuses. The posterior lymphatic plexus displays polygonal figures of smaller size and in greater number than observed in the anterior plexus. Both plexuses respectively converge as ascending trunks that run towards the dorsal face of the foot. The superficial venous network in the heel is irregular consisting of triangular and quadrangular figures of small size.*

were arranged in polygonal figures that were obliquely oriented in posterior to anterior and lateral to the medial axis (*Fig. 6*).

The venous vessels of the sole were directly linked with the superficial veins of the dorsal portion of the foot which all drain into

the leg venous system. The distribution of the lymphatic vessels seemed to be similar. Due to its restricted anatomical aim, our study was not able to provide information on dynamic lymph flow.

## DISCUSSION

Our present report provides a further accurate understanding of the lymphatic sole network. In fact, the injection technique employed herein demonstrates a more effective and possibly more correct picture of the network than previous techniques that utilized mercury. It is quite possible that the mercurial compounds initially injected into the lymphatic vessels caused an extravasation to the venous sole making the lymphatic network appear oversized. The use of a specific dye such as the mass of Gerota and the selection of specific injection areas were crucial in the outcomes of our study.

The distribution of the lymphatic network in the sole exhibits a similar design and characteristics to that of the venous network as described earlier (1,2). Moreover, the mechanical pressure exerted upon the plantar area constitutes the basic component that defines the morphology of this lymphatic network. Both anterior and posterior regions are the areas that receive the greater pressures due to bearing the plantar support. There, the lymphatic vessels adopted the structure of a dense network that allows the absorption of the mechanical pressure. In contrast, in the middle region, which is a zone that bears a lower mechanical pressure, the distribution of the sole lymphatic vessels assumes a transverse disposition.

The lymphatic network of the plantar region may represent a functional lymphatic pump impelled by walking. Indeed, when trans-inguinal nodal lymphographies are performed upon mechanical stimulation of the sole of the foot, a radiosopic progression of contrast dye can be seen towards the iliac lymph nodes and the thoracic duct.

Although the dynamics of the lymphatic flow has not been considered herein, we await histological findings in order to gain further information on the presence or absence of lymphatic valves and their direction. This information would provide a more accurate insight on lymphatic flow.

The present findings indicate an anatomical substrate that may underline the importance of incorporating stimulation of the sole and encouragement of walking in lymphatic rehabilitation treatment. Both therapies could be beneficially applied in order to improve the circulation of the lymphatic flow based on our anatomical findings.

## CONFLICT OF INTEREST AND DISCLOSURE

All authors declare no competing financial interests exist.

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