Lymph channels in the leg

Lymphbahnen am Bein

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ABSTRACT

Lymphedema is one of the complications of varicose vein therapy. Pittaluga and Chastanet found lymphedema in only 0.25 % after surgical intervention. Flessenkämper and colleagues were able to show that this occurs in 2.8 % (high ligature and stripping) to 9.2 % (endovenous laser ablation), depending on the therapy method used. One of the possible reasons for this lymphedema could be a direct damage of the (sub-)inguinal lymphatic vessels. In an anatomical study, a fine "VSM removal scar" was found on the medial left thigh, probably after a crossectomy. All collectors that passed through the scar obliterated at the scar while moving to the large inferolateral lymph nodes. Laterally to the scar they had a normal appearance and could be recannulated. Up to now, (anatomical) research has paid little attention to this aspect; however, it has been shown that several lymph vessels run underneath the saphenous fascia, parallel to the great saphenous vein. In the exploratory anatomical study presented here, twenty lower extremities of ten individuals were used.
The right-hand specimens were meticulously dissected in layers of the subinguinal region as far as possible. The left specimens were frozen and cut half longitudinally and half transversely. The resulting sections were examined for the exact course of the fascia lata, the cribrous fascia and the saphenous fascia and the exact location of the lymph nodes and pathways was determined.
Extensive intervention on the proximal saphenous vein, whether in classical crossectomy or in various endovenous procedures, the respective agent of which may extend beyond the venous wall itself, can lead to at least partial damage to accompanying lymph vessels. In most cases, the total transport capacity of the superficial lymph channels of the leg is not reduced below the lymphatic load; however, a pre-existing impairment or a later occurring further reduction of the total transport capacity can result in lymphedema.

ZUSAMMENFASSUNG

Zu den Komplikationen der Varizentherapie zählt auch das Lymphödem. Pittaluga und Chastanet fanden nach chirurgischer Intervention in nur 0,25 % ein Lymphödem. Flessenkämper und Mitarbeiter konnten zeigen, dass dieses, je nach verwendeter Therapiemethode, in 2,8 % (hohe Ligatur und Stripping) bis 9,2 % (endovenöse Laserablation) auftritt. Einer der möglichen Gründe für diese Lymphödeme könnte eine direkte Schädigung der (sub)inguinalen Lymphgefäße sein. In einer anatomischen Studie fand sich an einem Präparat eine feine „VSM-Entnahmenarbe" am medialen linken Oberschenkel, vermutlich nach einer Crossektomie. Alle Kollektoren, die die Narbe durchquerten, obliterierten an der Narbe, während sie auf die großen inferolateralen Lymphknoten zogen. Seitlich der Narbe hatten sie ein normales Aussehen und konnten rekanüliert werden. Bislang hat die (anatomische) Forschung diesem Aspekt wenig Beachtung geschenkt; dabei zeigte sich jedoch, dass auch unterhalb der Fascia saphena, parallel zur V. saphena magna, mehrere Lymphgefäße verlaufen.
In der hier präsentierten explorativen anatomischen Untersuchung wurden 20 untere Extremitäten von 10 Individuen verwendet.
An den rechten Präparaten wurde eine akribische und soweit wie möglich schichtweise Präparation der Subinguinalregion durchgeführt. Die linken Präparate wurden gefroren und zur Hälfte longitudinal und zur anderen Hälfte transversal geschnitten. Die so erhaltenen Schnitte wurden auf den genauen Verlauf der Fascia lata, der Fascia cribrosa und der Fascia saphena untersucht und die genaue Lage der Lymphknoten und -bahnen wurde festgestellt.
Eine extensive Intervention an der proximalen V. saphena magna, sei es bei der klassischen Crossektomie oder bei

diversen endovenösen Verfahren, deren jeweiliges Agens über die Venenwand selbst hinausreichen kann, kann zu einer zumindest teilweisen Schädigung von begleitenden Lymphgefäßen führen. Zumeist wird wohl die Gesamttransportkapazität der oberflächlichen Lymphbahnen des Beins nicht unter die anfallende Lymphlast gesenkt; jedoch kann eine vorbestehende Beeinträchtigung oder auch eine später auftretende weitere Minderung der Gesamttransportkapazität in einem Lymphödem resultieren.

Introduction

Lymphoedema is one of the complications of varicose vein treatment. Pittaluga and Chastanet found lymphoedema in only 0.25 % of their patients after surgical intervention [1]. Flessenkämper and co-workers showed that, depending on the treatment method used, lymphoedema was present at the first follow-up visit after surgery in four patients in the high ligation and stripping group, the same number in the high ligation and endovenous LASER ablation (EVLA) group and in two patients, who had EVLA alone (without surgical high ligation). The follow-up check after two months showed oedema in 2.8 % (high ligation and stripping) to 9.2 % (EVLA) of the patients. None of the results showed significant differences between the groups; long-term results have not been published [2] (see also ▶ **Table 1**). One of the possible reasons for the lymphoedema could be direct damage to the (sub-)inguinal lymphatic vessels. An anatomical study found a fine "GSV removal scar" on the medial left thigh in one specimen [3]. All the collectors running through the scar towards the large inferolateral lymph nodes were obliterated at the scar. Lateral to the scar they had a normal appearance and could be recannulated. To date, (anatomical) research has paid little attention to this aspect [4–6]; however, it has been shown that several lymph vessels run beneath the saphenous fascia, parallel to the great saphenous vein [5].

Fasciae in the leg

As an introductory step, the basic fascial relationships for the abdomen and legs must be presented and standardised (▶ **Table 2**).

With the exception of just a few regions, the entire body is enveloped in a superficial connective tissue sheath – the superficial fascia (*fascia investiens,* from the Latin *investīre*: to clothe). This superficial fascia is attached to the intermuscular septa and to the underlying skeletal elements, forming the osteofibrous spaces, which are known as compartments.

The superficial fascia also forms the innermost layer of the subcutaneous tissue. More or less complete septa extend from the superficial fascia to the dermis, firstly to connect this to the superficial fascia and secondly to organise the subcutaneous lobules of adipose tissue. The subcutaneous septa themselves are in turn connected to each other by superficial parallel lamellae of connective tissue, the subcutaneous fascia (*fascia subcutanea*). This subcutaneous fascia is mostly a three-dimensional sieve-like structure; in some places, it is therefore also known as the cribriform fascia (*fascia cribrosa* or *lamina cribrosa*).

The large body cavities are each lined by their own fascial sheaths; the transversalis fascia (*fascia transversalis*) in the abdomen and the internal thoracic fascia (*fascia thoracia interna*) in the chest.

Besides these superficial fasciae and fascial sheaths, each organ and each muscle has its own particular fascia. If a muscle fascia lies directly on the inner aspect of the superficial facia, the two connective tissue layers merge, so that from the outside it appears that the muscle is covered by only the superficial fascia.

However, it is not only in the abdomen and the legs that the major problem of very inconsistent terminology for the fasciae is evident, which is unfortunately also reflected in the "official" Terminologia Anatomica [7].

The superficial fascia of the abdomen is actually the deep layer of the superficial (investing) fascia of the abdomen (***fascia investiens (profunda) abdominis*** or *fascia abdominalis superficialis, lamina profunda*) [7]; it covers the external oblique muscle of the abdomen (*m. obliquus internus abdominis*) and the rectus sheath, to which it is firmly fixed. At the superficial (external) inguinal ring (*anulus inguinalis superficialis*), it extends as the thin external spermatic fascia (*fascia spermatica externa*) over the round ligament of the uterus (*ligamentum teres uteri* (♀)) or the spermatic cord (*funiculus spermaticus* (♂)). It was also named Scarpa's fascia after the Italian anatomist and surgeon Antonio Scarpa (1752–1832). The superficial fascia of the abdomen continues in the thigh as the **fascia lata**.

In the case of the ***fascia lata***, there is an overlap between the official terminology and the common name, although strictly speaking the Latin term should be *fascia investiens femoris.* But here, too, the eponymous term of Scarpa's fascia may sometimes be used. The saphenous opening (*hiatus saphenus)* in the fascia lata provides passage for the great saphenous vein (*v. saphena magna*). In the lower leg, the crural fascia is the common name for the *fascia investiens cruris*.

In the subcutaneous adipose tissue of the abdomen (*panniculus adiposus abdominis*), there is a honeycombed perforated connective tissue structure; this is officially called the ***fascia investiens superficialis*** *(abdominis)* [7], but is generally known as the *fascia abdominalis superficialis, lamina superficialis,* i. e. the superficial layer of the superficial fascia of the abdomen. An earlier – but meaningful – term was the subcutaneous fascia (of the abdomen) (*fascia subcutanea (abdominis))*. It is also known as Camper's fascia, after the Dutch anatomist and surgeon Peter Camper (1722–1789).

This superficial abdominal fascia (*fascia investiens superficialis (abdominis))* continues naturally into the thigh to form the subcutaneous fascia of the thigh (*fascia subcutanea femoris),* although the latter does not have an official name. It is only in the region of the saphenous opening that it merits the designation cribriform fascia (***fascia cribrosa)*** [7].

▶ **Table 1** Lymphoedema as a complication of varicose vein treatment.

complication rate	treatment modality	reference
0.6 %	sclerotherapy (PSTS)	Cavezzi, Frullini, Ricci, et al. [27]
0.9 %	high ligation (with barrier)	De Maeseneer, Philipsen, Vandenbroeck, et al. [28]
1.3 %	high ligation & stripping	De Maeseneer, Vandenbroeck, Lauwers, et al. [29]
6.9 %	high ligation & stripping	Figueiredo, Araujo, Barros, et al. [30]
0.0 %	sclerotherapy (polidocanol)	
2.8 %	high ligation & stripping	Flessenkamper, Hartmann, Stenger, et al. [2]
9.2 %	EVLA (980 nm)	
6.3 %	EVLA (980 nm) & high ligation	
0.2 %	high ligation & stripping	Pittaluga and Chastanet [1]

▶ **Table 2** Fasciae of the abdomen and legs.

common term(s)	terminologia anatomica [7]	eponymous term
Superficial investing fascia of the abdomen; Superficial fascia of the abdomen, superficial layer; Subcutaneous fascia	Fascia investiens superficialis abdominis	Camper's fascia
Deep investing fascia of the abdomen; Superficial fascia of the abdomen, deep layer	Fascia investiens profunda abdominis	Scarpa's fascia
Cribriform fascia; Subcutaneous fascia	Fascia cribrosa	≈ Camper's fascia
Saphenous fascia		
Fascia lata	Fascia lata (≈ Fascia investiens femoris)	≈ Scarpa's fascia
Crural fascia	Fascia cruris (≈ Fascia investiens cruris)	

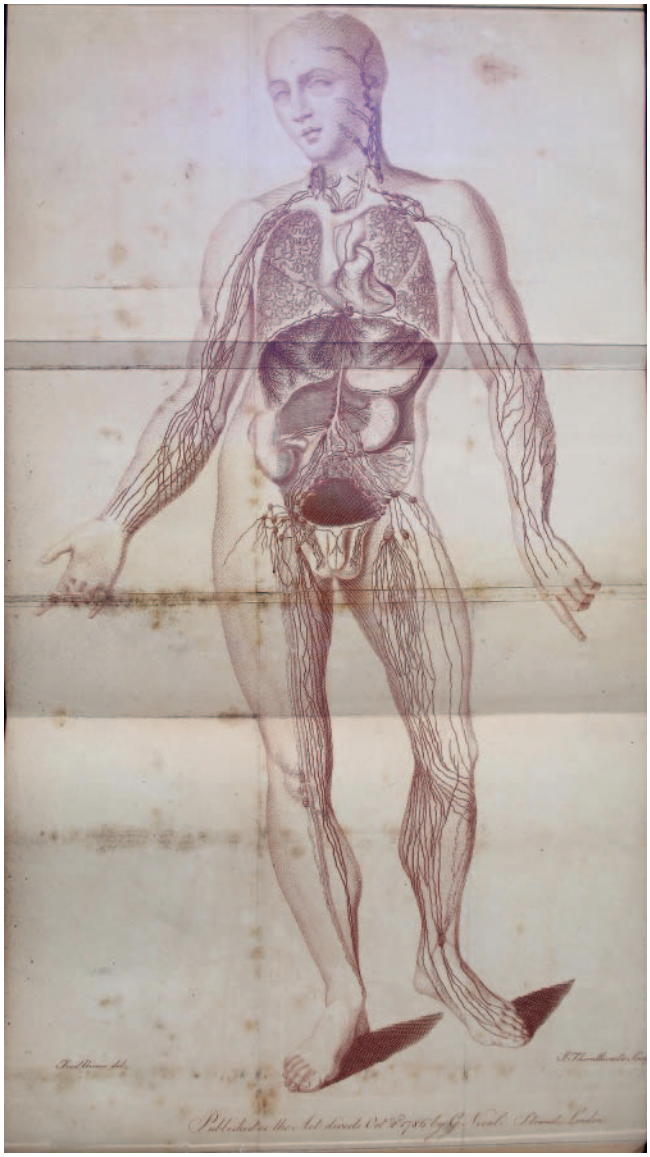
In 1997, Alberto Caggiati and Stefano Ricci first described the compartment of the great saphenous vein and the saphenous fascia (*fascia saphena)* in an anatomical specimen [8]. They found that, for the greater part of its length, the great saphenous vein is confined in a narrow compartment running deep in the muscle fascia [author's note: meaning the superficial investing fascia, *fascia investiens superficialis*] and superficially through a connective tissue layer, which descends from the inguinal ligament into the anteromedial aspect of the thigh and medial aspect of the lower leg. These two fasciae merge at the boundaries of the compartment. The adventitia of the great saphenous vein is anchored to both fasciae by thick strands of connective tissue. Their figure 3A shows that the saphenous compartment is narrow except in the groin, where the saphenous fascia gradually becomes superficial. Therefore, to summarise: distal to the saphenous opening, the great saphenous vein is covered by its own saphenous fascia, whereby it is separated from the actual subcutaneous adipose tissue and runs in its own saphenous compartment [9].

Historical descriptions and illustrations

Descriptions and illustrations of the superficial lymphatics in the leg go back a long time in history. In 1786, William Cruikshank presented the first summarised description of the lymph nodes and lymph vessels of the leg [10], although he stated that the first description of these lymph vessels could be attributed to Johannes van Horne. At that time, Cruikshank reported that the superficial lymphatics of the leg accompanied the two veins and therefore called them the '*vasa lymphatica venam saphenam majorem comitantia*' and '*vasa lymphatica venam saphenam minorem comitantia*'.

Cruikshank described these lymph vessels in the following manner[1] (see ▶ **Fig. 1**): *'They form four great divisions: the first arises from between the great toe and the one on its outside, where the saphena major commences, and consists of six or seven vessels; they run over the top of the foot, with that vein, towards the fore part of the inner ankle; from thence they run, in company with the vein, towards the inside of the knee, where they are joined by others, presently to be described. The second division, which I have seen consisting sometimes of eight or ten vessels, arise about the middle of the inner edge of the foot, pass behind the inner ankle and, running over the inside of the calf of the leg, join the last-described vessels on the inside of the knee. The third division, consisting of five or six vessels, arise near the little toe, run over the outer and upper side of the foot, in the direction of the outer ankle; when they come near to it, they divide into two; one part crosses over the anterior part of the tibia and go likewise to the inside of the knee, where they join the two former divisions. […] From the union of these three divisions, a grand plexus is formed, consisting of fourteen, sixteen or twenty trunks, which still continue to accompany the saphena major; that is, to run obliquely from the inside of the knee to the middle of the groin; there they commonly go into the different inguinal glands already described. […] It frequently happens, that two or three of these trunks pass by the glands of the groin and are not inserted into any gland until they have passed under Paupart's [the inguinal] ligament. Part of that last division, viz. that coming from the little toe, join another, which arises from the middle of the outer edge of the foot, where the saphena minor commences, and accompanying that vein, pass behind the outer ankle; from thence run on the outside of the Achilles tendon, go afterwards between the bellies of the gastrocnemius muscle and, dipping down between its heads, near the place where they*

1 The German translation was done by the author using modern terminology. Cruikshank's text with the original grammar and spelling is given here, with Prof. Brenner's updates added in parenthesis.



▶ **Fig. 1** Plate I from Cruikshank (1786) [10].
[…] The left leg represents the cutaneous absorbents in my [William Cruikshank's] most successful injection of these vessels […].
The right leg represents not only the cutaneous, but also the deep-seated absorbents. […] The dotted lines show the deep-seated absorbents. […]

are inserted into the condyles of the os femoris, terminating in the glands of the ham [popliteal fossa], already described. […] These are not above one fifth so numerous as the former.'

Cruikshank describes the popliteal lymph nodes n the following manner:

'I have not seen any glands in the lower extremity, below the ham. […] There are seldom more than three, they lie close upon the popliteal artery and, though small, are by no means, as Haller says "uti ultimae conglobatarum, ita minimae" [approximately: "as if extremely crowded, so minimal in size"]. *"There are many on the mesocolon and in a variety of other places, much smaller than they are. They swell from sores on the outside of the foot, in the sole of the foot and from sores of the integuments on the calf of the leg"*

And Cruikshank had this to say on the inguinal lymph nodes: *"The glands of the groin are of an uncertain number, from eight, ten or twelve up to twenty or more. Haller makes them only four. They are situated, principally, above the fascia of the thigh, though several of them lie under it. These last are placed on the iliacus internus muscle, between the triceps [quadriceps] and sartorius. Sometimes several of these glands are collected into one large one, which lies on the upper side of the inguinal [femoral] artery. Those that are nearest the symphysis pubis belong to the absorbents of the parts of generation [genitalia] in both sexes and become, in the venereal disease, the seat of buboes. […] Those on the outside of these last-mentioned are more apt to inflame and enlarge from scrophulous or other sores on the inside or the top of the foot, from sores on the inside of the knee or anywhere in the course of the saphena major. They may swell from sores anywhere on the inside or fore part of the leg or thigh. I have known them swell from wounds of the buttocks and even from the inflamed and bleeding piles around the verge of the anus. When plasters, producing ulcers in the integuments, have been applied to the skin, near the spine of the ilium, I have also repeatedly seen these glands swell. They sometimes swell and suppurate, from sympathy with an inflamed testicle [even though there is no lymphatic vascular connection between them]. Haller and Nuck make these glands extend sometimes to the middle of the sartorius muscle […]. I have seldom seen any glands between the popliteal and inguinal glands, neither with the cutaneous nor with deep-seated lymphatics."*

Paolo Mascagni, a young anatomist in Siena, published a detailed monograph of his findings in 1787 [11]. The three-dimensional wax model of the lymphatic system by Felice Fontana, which can be found in the *Museo La Specola* in Florence, can also be attributed to Mascagni's exemplary preparations [12]. It is interesting that although Mascagni described the deep lymph vessels of the lower extremity and the inguinal lymph nodes in great detail, he did not describe the superficial lymph vessels. From today's perspective, the classification of these lymphatics in his Plate IV (▶ **Fig. 2**) seems to be rather arbitrary. It is also of interest that Christian-Friedrich Ludwig made a contemporary translation of Mascagni's monograph into German in 1789, together with Cruikshank's book cited previously [13, 14].

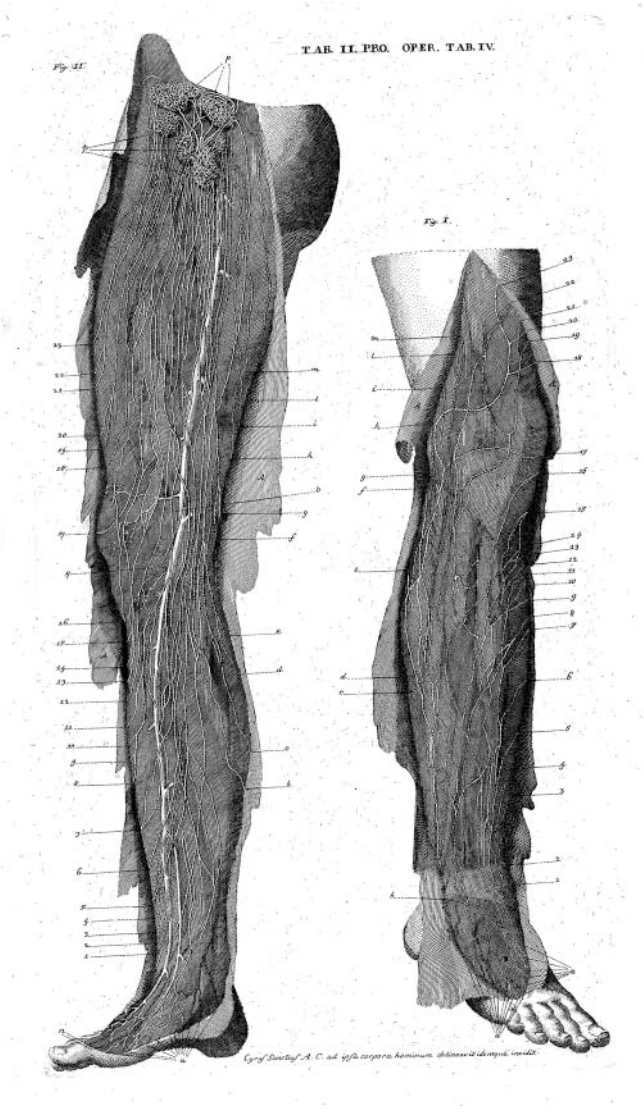
FIG. 2 PLATE IV FROM MASCAGNI (1787) [11].

Figure 1

- Dissected skin reflected to each side
- a Lymph trunks, into which the injections were made
- b – g Trunks running from the outside to the back
- h i l m Trunks that migrate from the inside to the back of the lower hip
- 2. – 17. Trunks arising from the inside of the lower leg
- 18. – 23. Trunks that run from the inside to the front of the lower hip

Figure 2

- Entire skin dissected and reflected.
- a Nine lymph trunks arising from the sole of the foot, into which the mercury was injected



▶ **Fig. 2** Plate IV from Mascagni (1787) [11].

- b – g Trunks coming from the back of the lower leg running to the inside of the leg.
- h i l m Other trunks migrating from the back of the hip to the inside
- n Two lymph trunks arising from the great toe, into which the mercury was injected
- 2. – 17. Lymph trunks with the same numbers as in ▶ **Fig. 1** and those running from the front to the inside of the tibia
- 18. – 23. Trunks of the same vessels running from the outside to the front of the hip
- Trunk running between the sartorius and vastus medialis muscles to join with the deep lymph vessels
- p Six lymph nodes, into which the previously described lymph vessels empty
- q Great saphenous vein, tributary branches resected

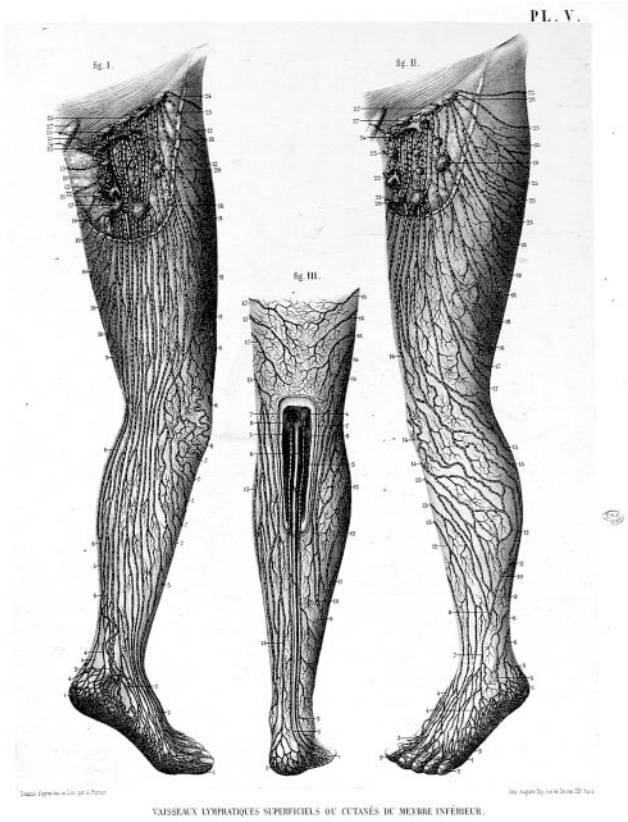
The next qualitative step was taken by Philibert Constant Sappey in 1874, with his treatise on the anatomy, physiology and pathology of the lymph vessels [15]. His description of the lymph channels is extremely detailed and the work is illustrated with many etchings (▶ **Fig. 3**).

FIG. 3 PLATE V FROM SAPPEY (1874) [15]

Plate V

Fig. I Lymph vessels of the anteromedial aspect of the lower extremity

1, Lymphatic network of the inner edge of the foot. A considerable number of trunks arise from this network: they wind under the skin and converge into collectors.
2, Lymph trunks from the peripheral network of the toes and the front half of the sole
3, Large lymph trunk arising from the central plantar region and passing in front of the medial malleolus
4, Lymph trunks that come from the inferior and posterior aspects of the skin over the heel
5, Lymph vessels of the inside of the leg
6, Lymph vessels from the back
7, Trunks that run from the outside leg to the inside leg
8, Trunks that pass around the front of the knee: they are noteworthy for their volume and particularly for their numerous bends, which disappear on flexing the joint
9, Lymph trunks of the anteromedial part of the thigh
10, Trunks from the posteromedial part of the thigh
11, Trunks that come from the posterolateral part
12, Trunks arising from the posterior cheeks
13, Trunks extending from the inner part of the buttocks and the anal region
14, Trunks arising from the membrane of the synovial bursa
15, Another trunk, coming from the erectile parts of the penis
16, A large lymph node, to which most of the trunks on the inside of the leg and thigh run
17, A further lymph node, also large, in which most of the trunks from the back and inside of the thigh terminate
18, Large trunks running from the previous ganglia, ascending vertically to the anterior of the femoral artery and ending in a lymph node that is located on the external iliac artery immediately above the inguinal ligament
19, A further sizeable efferent trunk, which runs in front of the femoral vein and enters the same lymph node
20, Lymph node that receives the vessels of the anterolateral part of the thigh
21, The lymph node, in which most of the vessels from the anteromedial part of the thigh terminate
22, Terminal end of the great saphenous vein, from which a part has been removed, in order to expose the underlying lymph trunks
23, Lymph node to which the vessels from the penis lead
24, Lymph node that receives nearly all the vessels from the lumbar region and some of the vessels from the gluteal region
25, Lymph nodes found on the extension of the previous one, to which they are connected by the efferent ganglia that leave



▶ **Fig. 3** Plate V from Sappey (1874) [15].

them. These lymph nodes receive the vessels from the anterior abdominal wall.
26, Lower part of the fascia of the external oblique muscle
27, External inguinal ring, which is crossed by the spermatic cord

Fig. II – Lymph vessels of the anterolateral aspect of the lower extremity
1, Lymphatic network of the outer edge of the foot; trunks arising from this network; when they converge, they form trunks that ascend obliquely over the back surface.
2, Lymphatic network of the periphery of the toes
3, Lymph trunks, some arising from this network, some coming from the metatarsal region of the sole of the foot
4, Lymph trunks of dorsum of the foot
5, Origin of the vessels that accompany the small saphenous vein
6, Lymph trunks that follow this vein and end in the popliteal fossa ganglia
7, Consistently large trunk, which runs over the lateral malleolus and, with its subsequent bifurcations, creates nearly all the vessels of the outside of the leg
8, 9, First and second bifurcations of this main trunk. The first division is usually found 4 cm above the lateral malleolus.
10, 11, Third and fourth forks, usually very close to the previous ones
12, Lymph vessels on the outer surfaces of the leg. These mostly large vessels are variably curved in different directions and connected by frequent anastomoses.
13, Lymph trunks running from the outside of the leg to the inside and intersecting the tibial crest obliquely
14, Another trunk, which is bulky and alternately curved in different directions, running around the front of the knee to be carried inwards and upwards
15, Two lymph trunks from the skin of the back of the leg
16, All trunks of the anterolateral part of the thigh
17, Two trunks that arise from the skin of the popliteal fossa and rejoin after a short distance
18, Trunks arising from the back of the thigh and going around the outside of it
19, Lymph node, into which these four trunks go
20, Large lymph node that receives the major vessels from the anteromedial part of the extremity
21, Lymph node that receives the trunks of the posterolateral part of the thigh
22, Terminal end of the great saphenous vein.
23, Lymph node, into which the vessels from the perineum, the anal region and the medial part of the buttocks empty
24, Lymph node into which most of the lymph vessels from the external genitalia flow
25, Lymph trunk from the gluteal region.
26, Lymph node that receives this vessel
27, Lymph nodes, into which the vessels from the sub-umbilical part of the anterior abdominal wall empty

Fig. III – Lymph vessels of the back of the leg
1, Lymphatic network of the lateral edge of the foot, from which several trunks arise; the two most important run to the back; these are the peroneal saphenous trunks.
2, These two lymph trunks are found on either side of the small saphenous vein, running parallel to it
3, Trunk of the outer peroneal saphenous group
4, Lymph node, in which it terminates
5, Lang peroneal saphenous trunk, which plunges into the popliteal fossa to reach a less superficial lymph node than the previous ones
6. Small saphenous vein (vena saphena parva)
7, Edge of the skin incision
8, Edge of the incision of the leg fascia, under which the peroneal saphenous trunk passes through in the upper half of its course
9, Large trunk that runs over the lateral malleolus and creates nearly all the vessels of the outside of the leg through its subsequent bifurcations
10, Its second bifurcation
11, Third bifurcation
12, All lymph vessels that come from this trunk
13, Posteromedial vessels of the leg
14, Two trunks running from the back of the leg to the anterolateral part of the thigh
15, Another trunk that after running on the back of the leg, passes round the knee to the medial part of the thigh

16, Three trunks coming from the posteromedial thigh, then running around the outside of the thigh to reach the front
17, Other trunks, originating from the same point as the previous ones, but running to the inside of the thigh rather than to the outside, to connect with the vessels on the inside of the thigh

More recent descriptions

More recently, several authors have been concerned with the relative positions of the superficial lymphatics and the great saphenous vein. Two of the first were Stefan Kubik and Mirjana Manestar in 1995 [16]. According to their findings, the collectors cross over the veins in the dorsum of the foot, in all other regions they cross under them. Only the great saphenous vein has collectors crossing over it again. It also has accompanying lymph vessels, but its outer layer (*tunica adventitia*) does not contain any. The position of the collectors ultimately depends on the thickness of the subcutaneous adipose tissue. On the dorsum of the foot, the lymphatics are often closely bound to the dermis; in the lower leg, however, they are embedded in the adipose tissue. A few collectors are closely linked to the perforating veins. Around the knee, the lymph bundle ascends posteromedially to the medial femoral condyle. In the thigh, where the subcutaneous adipose tissue is thick, the collectors form three layers. The superficial inguinal lymph nodes draining the leg and the external genitalia are situated around the saphenous opening and are closely linked to the subinguinal saphenofemoral junction.

In 2009, Vivien Schacht and co-workers then re-examined the anatomy of the subcutaneous lymph vascular network of the human leg in relation to the great saphenous vein [4]. They found that the lymphatic collectors on the dorsum of the foot ran in close parallel to the dermis, whereas in the groin a greater number of lymphatic collectors were clustered around the great saphenous vein. The anteromedial bundle that drains into the superficial inguinal nodes consisted of 5–20 lymph collectors. The average width of the anteromedial bundle varied between 116 mm in the middle of the lower leg and 32 mm at the groin. At the talocalcaneal joint, in the lower leg and at the knee, many lymph collectors were distributed away from the great saphenous vein, while in the middle of the thigh and at the groin, the lymph collectors were concentrated within 3–5 cm anterolateral to the great saphenous vein. Schacht et al. were not able to confirm the earlier assumption of a 'bottleneck' in the anteromedial lymphatic bundle at the knee. In addition, their data did not support the hypothesis of a single sentinel lymph node for a specific region of the leg.

In 2013, the team led by Saam Tourani investigated the anatomy of the superficial lymph vessels of the abdominal wall and of the thigh and its implications in lymphatic microsurgery [3]. The upper and lower abdominal collectors were found above Scarpa's fascia (*fascia investiens abdominis*), immediately below the subdermal venules. The collectors were thin-walled and translucent, with diameters ranging between 0.2 mm and 0.8 mm. In the thigh, two distinct groups of superficial collectors were found. The collectors of the anteromedial bundle constituted the majority of the superficial collectors; they were deep in the subcutaneous fat, measured 0.6–1 mm in diameter, had thick walls and drained continuously into two large nodes located inferolateral to the saphenofemoral junction. The local collectors of the thigh were immediately below the subcutaneous venules, 0.3–0.5 mm deep, had thin walls and drained into the superolateral group of superficial inguinal nodes, which also drained the lower abdomen, the lower back and the upper gluteal region.

Also in 2013, Pan Wei-Ren and co-workers investigated the superficial lymphatic drainage of the lower extremity [6]. In doing so, they were able to identify numerous lymph collectors in the subcutaneous tissue and in the superficial femoral vascular bundle of the lower extremity. These collectors originated beneath the dermis of each side of the toes, the foot and the lateral aspect of the thigh. The diameters of the vessels ranged from 0.2 mm to 2.2 mm. The vessels ran in the subcutaneous tissue of the lower limb towards the popliteal and femoral lymph nodes as well as the superficial and deep inguinal lymph nodes. During their tortuous course, some vessels branched, diverged and converged; sometimes anastomosing with neighbouring vessels or crossing them. Most vessels converged to form larger collectors and then divided into smaller branches before entering the lymph nodes.

A year later, Pan et al. described the various lymphatic drainage routes from the heel to the inguinal region [17]. They identified thereby two groups of lymph collecting vessels. The medial group, which arises from the skin between the medial malleolus and the Achilles tendon, ran along the medial side of the leg and thigh to the inguinal lymph nodes. The lateral group, which arises from the skin between the lateral malleolus and the Achilles tendon, ran along the posterolateral side of the leg to the popliteal fossa. Alternative routes were then identified from the popliteal fossa to the inguinal lymph nodes. The number, size, type and distribution of the lymph vessels and nodes varied from person to person.

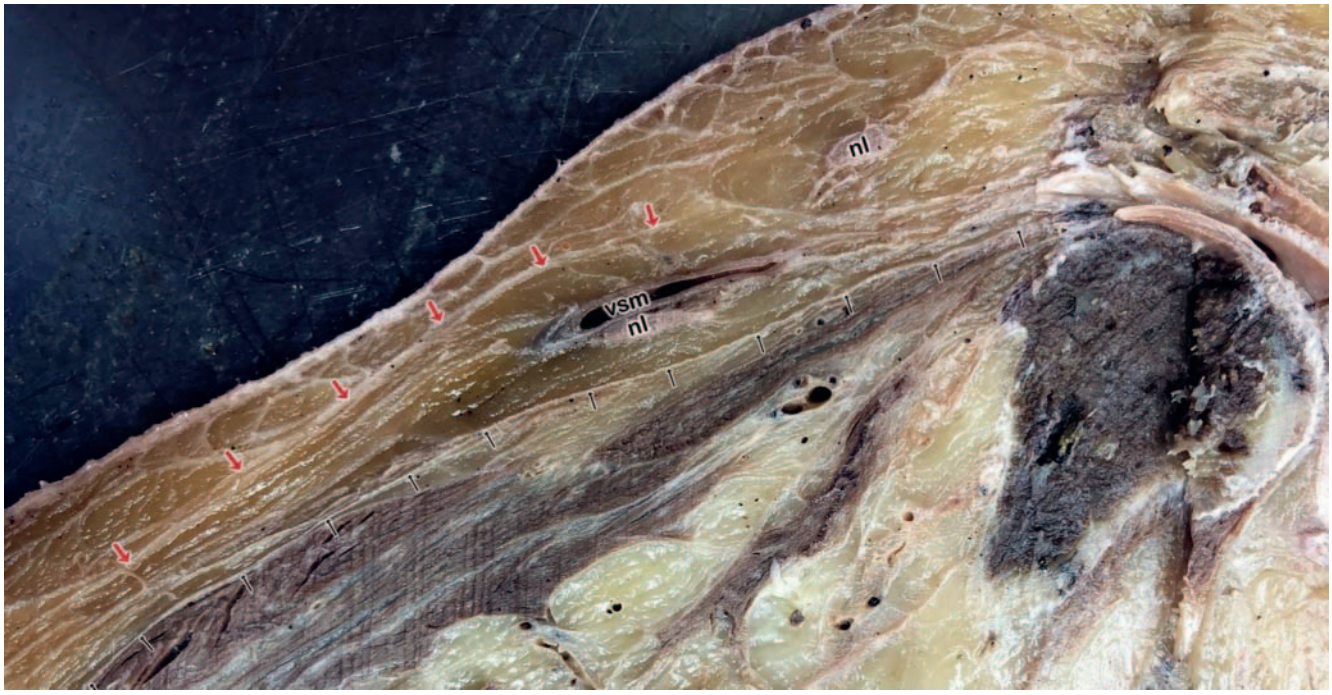
Materials and methods

The exploratory anatomical study presented here looked at 20 lower limbs from ten individuals, both men and women, who during their lifetimes had willed their bodies to the Institute of Clinical and Functional Anatomy, University of Innsbruck, Austria for scientific and teaching purposes [18, 19].

All bodies were preserved by the arterial injection of a formaldehyde-phenol solution or an alcohol-glycerine solution and stored for three months in a phenol 5 % aqueous solution [20].

With respect to representativeness, a recent analysis showed that the bodies donated to the Institute of Clinical and Functional Anatomy, University of Innsbruck, constituted a representative sample of the general Austrian population at the time of death [21].

A meticulous dissection of the subinguinal region, as far as possible in layers, was performed on the right limb. The left legs were frozen; half of them were cut longitudinally and half transversely. The sections so obtained were examined to ascertain the precise course of the fascia lata, the cribriform fascia and the saphenous fascia and establish the exact positions of the lymph nodes and channels.



▶ **Fig. 4** Longitudinal section through the thigh, approximately parallel to the great saphenous vein.
vsm: great saphenous vein; nl: lymph node; black arrow: fascia lata; red arrow: saphenous fascia.
As already described by Caggiati and Ricci [8], the saphenous fascia lifts off from distal to proximal. The initially very compact saphenous fascia breaks up into fine layers that together form the cribriform fascia. There is no evidence of a direct connection between the saphenous fascia and the inguinal ligament.

Results

The great saphenous vein ascends on the anteromedial thigh in the saphenous compartment, formed by the saphenous fascia and the fascia lata. It is accompanied by several collectors of the anteromedial bundle [5]. Further collectors from this bundle lie superficial to the saphenous fascia. In the proximal thigh, the saphenous compartment broadens out, while the saphenous fascia lifts off and becomes part of the cribriform fascia (▶ **Fig. 4**).

Up to 20 lymph collectors are to be found in this widened space [4], mostly lateral to the great saphenous vein; they lie not only superficial, but also deep to the vein. Just before the saphenofemoral junction, at a distance of up to 5 cm, there are several lymph nodes in close contact with the great saphenous vein, once again, mostly lateral (▶ **Fig. 5**); the number varies greatly from person to person and, although they are crosslinked by numerous lymph vessels, they are not connected to any of the superficial lymph nodes involved in the pathway draining the superficial abdominal wall.

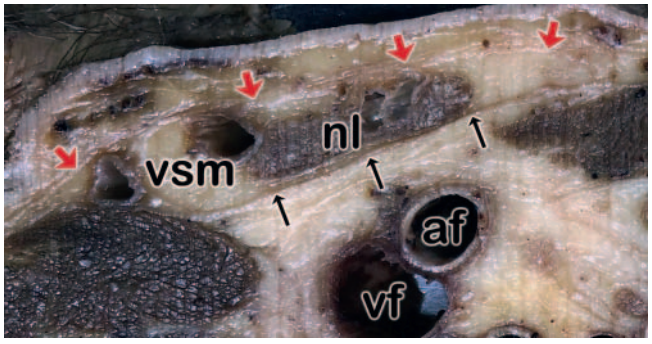
The actual efferent lymphatics from these superficial inguinal nodes of the leg mostly pass through the saphenous opening along with the great saphenous vein and then empty from there into the deep inguinal nodes (▶ **Fig. 6**).

In the lower leg, the saphenous nerve also accompanies the great saphenous vein in its saphenous compartment. The saphenous nerve is a cutaneous sensory branch of the femoral nerve. In the thigh, it passes into the adductor canal together with the femoral artery and vein, but then penetrates the vastoadductor membrane and subsequently enters the musculofascial tunnel of the sartorius muscle. It is not until the level of the popliteal fossa, where the sartorius muscle turns anteriorly to the pes anserinus, that the saphenous nerve penetrates the fascia lata – usually posterior to the great saphenous vein – to run distally within the saphenous compartment. Its cutaneous branches, the infrapatellar branch and the medial crural cutaneous branches, subsequently penetrate the saphenous fascia to innervate the skin distal to the patella and on the medial aspect of the lower leg.

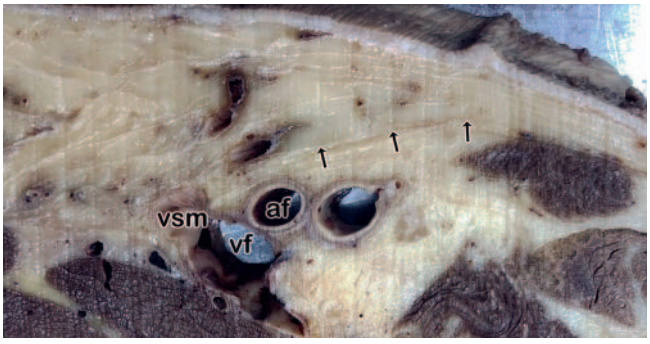
Discussion

Most of the superficial lymph drainage in the leg takes place through lymph vessels or lymph collectors that run alongside the great saphenous vein; only a small proportion from the lateral aspect of the heel, the outer side of the ankle and a small strip of the posterolateral lower leg empties into the deep collectors at the level of the popliteal fossa.

These lymph vessels naturally have to cope with the lymphatic load, but as is the case everywhere, there is generally a large reserve capacity [22–24]. There are no precise data, but it is estimated that the normal physiological lymph volume at rest represents only about 20 % of the maximum transport capacity; some authors even say only 10 % [25]. This large reserve capacity is necessary to allow sudden rapid increases in the lymph load – due to inflammation or trauma, for example – to be collected and transported. If only a few lymphatics are non-functional, the remaining lymph vessels can take over their transport function, although this increases the lymph transport in these vessels.



▶ **Fig. 5** Transverse section through the thigh, approximately 5 cm distal to the saphenofemoral junction.
vsm: great saphenous vein; nl: lymph node; af: femoral artery; vf: femoral vein; black arrow: fascia lata; red arrow: saphenous fascia.
The great saphenous vein lies in the saphenous compartment formed by the fascia lata and the saphenous fascia. Lateral to the great saphenous vein, within the saphenous compartment, there is a large lymph node with efferent lymphatics that can be seen extending from the medulla. The posterior accessory saphenous vein (vena saphena accessoria posterior) runs medial to the great saphenous vein – outside of the saphenous compartment.



▶ **Fig. 6** Transverse section through the thigh at the level of the saphenofemoral junction.
vsm: great saphenous vein; af: femoral artery; vf: femoral vein; black arrow: fascia lata.
The section lies directly at the level where the great saphenous vein empties into the femoral vein, which is surrounded here by numerous small calibre lymph vessels. There is no distinct saphenous fascia; the individual lamellae of the subcutaneous connective tissue form the cribriform fascia.

There are no consequences, if the increase is only slight or short-lived, but if it is a large and long-term increase – possibly even permanent – the lymphatics become 'exhausted' by this increased work load and the transport capacity falls; if it falls below the ensuing lymph load, the result is lymphoedema. Only in the rarest of cases can it be assumed that the therapeutic procedure on the great saphenous vein is solely responsible for the development of lymphoedema. Firstly, there may have been unrecognised prior damage to the lymphatic system that had already reduced the maximum transport capacity, but not yet enough for it to lead to lymphoedema. Secondly, a further reduction in the maximum transport capacity may occur after treatment of the great saphenous vein, but independently of the intervention. The probability of lymphoedema depends on (1) the degree of possible prior damage to the lymphatic system, (2) the degree of damage to the lymph vessels from the therapeutic intervention on the great saphenous vein, and (3) the degree of later damage to the lymphatic system.

The 2-month follow-up data presented in the introduction largely rule out subsequent damage occurring independently. It was therefore the intervention on the venous system that damaged the lymphatics, reduced the maximum transport capacity to below the level required for the already increased lymphatic load and thus triggered the development of the lymphoedema.

At this point, it should again be emphasised that there is no "bottleneck" in the course of the lymphatic drainage of the leg, either at the knee [4] or anywhere else.

Some of the earlier studies have investigated the relationship of these lymph vessels to the great saphenous vein [4, 16], but none of them have so far shed any light on the relationship of the lymphatics to the saphenous fascia. In his own investigations, the author found that the lymph collectors ran not only beneath, but also above the saphenous fascia. He established that most of the lymph vessels lie lateral to the great saphenous vein – not only superficially, but also deep to the vein.

An extensive therapeutic procedure on the proximal great saphenous vein, whether with conventional high ligation or one of the various endovenous procedures, whose agents may extend beyond the vein wall itself, could cause at least partial damage to the accompanying lymphatics. In most cases, the total transport capacity of the superficial lymph channels of the leg does not fall below the ensuing lymph load; however, a pre-existing impairment or even a further reduction in the maximum transport capacity occurring later may result in lymphoedema.

From the anatomical point of view, a medial approach for surgical access to the proximal great saphenous vein and the saphenofemoral junction itself is to be recommended. In addition, it may be possible to bypass the subinguinal lymph node packet with its tributary lymph vessels and its interconnections, by performing a very superficial blunt dissection distally and medially from the skin incision and then going down deeper to reach the underlying fascia lata some distance from the saphenofemoral junction. It is then possible to continue the dissection on the fascia lata in a proximal direction towards the saphenofemoral junction and thus protect the lymphatics lying laterally and superficially [26].

Endovenous thermal procedures, on the other hand, carry the risk of also damaging any lymph channels that lie in the immediate vicinity of the great saphenous vein. An 'anatomical alternative' is not possible here, as this procedure has its effect directly within the vein. The only way to protect the surrounding lymphatics is by keeping the energy used as low as possible, but this would certainly be at the expense of the occlusion rate. The use of tumescence may displace some lymph vessels away from the great saphenous vein, but there are no pertinent studies or supporting data for this.

Conflict of interest

This publication is based on a presentation given at the 61st annual meeting of the German Society of Phlebology, held in Münster, Germany, in 2019 [31]. The author received travelling expenses for the presentation.

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