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Lymphatic Distribution and Drainage in the Anterior Lateral Thigh Flap

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Abstract **Review Article**

Since the anterior lateral thigh flap was introduced into clinical practice in 1984, it has been widely applied not only in the repair of skin and soft tissue defects of the head, neck, trunk and limbs, but also in the reconstruction as a part of some organs. Hence, it is known as the "universal flap". Subsequent basic research and clinical applications provided detailed information in the neurovascular supplies of the flap. However, the anatomical features of lymphatic distribution in the flap have never been described in detail. This article aims to provide a detailed explanation of the lymphatic anatomy of the flap based on previous research on the lymphatic system of the lower limb.

Keywords: Anterior Lateral Thigh Flap, Lymphatic Vessel, Lymph Node, Lymphedema, Low Limb.

INTRODUCTION

The anterior lateral thigh flap has been widely promoted and applied in clinical practice since it was introduced into reconstructive plastic surgery in 1984 (Xu, 1984; Luo, 1984). The flap has been widely used, not only for the repair of skin and soft tissue defects in the head, neck, trunk and limbs, but also for the reconstruction of some internal organs, therefore it is known as the "universal skin flap" (Xu, 2002). According to reports from either anatomical study or clinical practice, it was shown that the flap has many advantages. This includes a long and larger diameter vascular pedicle, a larger skin area for resecting, the ability to carry skin nerve for reconstructing sensation, minimal functional impact on donor site, relatively concealed location and convenient acquisition of body position (Taylor, 1994; Pan, 2009). Although, literature has shown the distribution and drainage of superficial and deep lymphatic vessels/nodes in the lower limbs (Pan, 2013; Pan, 2014; Pan 2016; Pan, 2017; Ma, 2021) the anatomical characteristics of the distribution of lymphatic vessels/nodes in this flap have not been detailed. This article aims to provide a detailed explanation of the lymphatic distribution of this skin flap based on previous lymphatic study of the lower limb.

The Research History of the Human Lymphatic System

The discovery of the lymphatic system was later than that of the arteriovenous system, as lymph vessels have a transparent wall making it difficult to identify in routine anatomical dissection. In the early 17th century, Aselli (Aselli, 1622) accidentally discovered lymphatic vessels in the mesentery of a well-fed dog while studying the anatomy of the recurrent laryngeal nerve. Subsequently, a series of studies on lymphatic dissection were conducted based on experiments conducted on animals and even humans after a full meal (Haagensen, 1972; Skandalakis, 1995). However, these experiments could only confirm that the chyle fluid was collected and drained by the mesenteric lymphatic vessels/nodes, which then flow into the cisterna chyle, subsequently into the thoracic duct, and finally into the vein at the venous angle formed by internal jugular and subclavian veins.

In 1692, Nuck introduced the technique of direct injection of mercury into lymphatic vessels, which made it possible to display lymphatic vessels in tissues other than the mesentery, cisterna chyle and thoracic duct (Skandalakis, 1995; Cruikshank, 1786). This technique became the main method for the lymphatic study for over a century in following days. Literature showed that results of lymphatic studies from Cruikshank (1876), Masgani (1787), Bonamy *et al.*, (1840), and Sappy (1874) were representative (Figure 1). Although their results have provided some anatomical knowledge of the human lymphatic system (Cruikshank, 1786; Bonamy, 1840; Sappy, 1874; Haagensen, 1972), some doubts still remained. For example, Figure 1A showed that the collecting lymphatic vessels on the outer thigh are not

displayed, while Figure 1C showed that the density of collecting lymphatic vessels on the inner and outer thighs were basically the same. Therefore, which scenario shows the correct anatomical characteristic of lymphatic distribution? It still needs to be confirmed by further study. However, due to the high toxicity of mercury, indirect injection methods (using dyes, ink, etc. as a medium) were used instead of mercury injection in subsequent studies. However, the research results using this method could not fully demonstrate the anatomical distribution of the human lymphatic system (Gerota, 1896). With the participation of clinical research, there has been rapid development in the basic research and clinical application of the lymphatic system (Haagensen, 1972). At present, most of the knowledge about the lymphatic system in textbooks is based on the results of these early studies, but sometimes this knowledge cannot explain some clinical findings (Uren, 1999; Thompson, 2004). For example, why did it appear in the inguinal lymph nodes on the opposite side after injecting isotopes into one foot (Reynilds, 2007). Therefore, in-depth research on the morphological structure and distribution of the human lymphatic system, as well as its relationship with surrounding tissues, blood vessels, and nerves, would undoubtedly provide an anatomical basis for related clinical applications and scientific research.

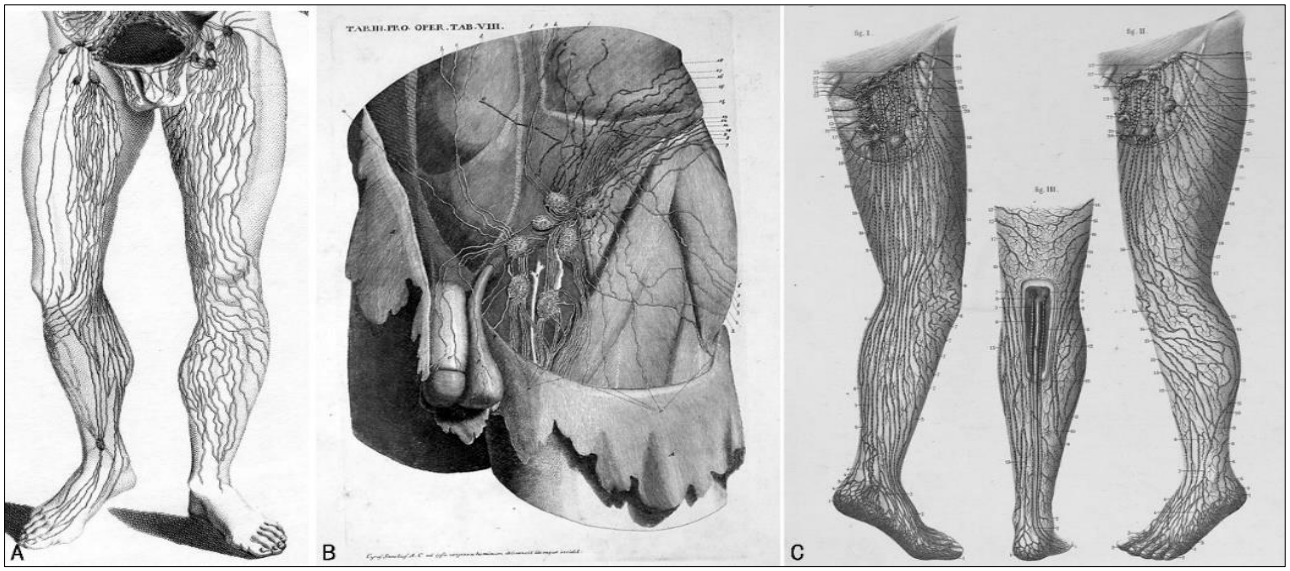

Figure 1: Distribution of superficial lymphatic vessels in the lower limbs of the human body (after mercury perfusion). A: The result of Cruikshank's study (1876); B: The result of Masgani's study (1787); C: The result of Sappy's study (1874).

At the beginning of this century, an improved lymphatic perfusion method was applied for studying the human lymphatic system (Suami, 2005), which involved injecting a small amount of hydrogen peroxide into the dermally or subcutaneous tissue of the fresh cadaver, then finding the dilated lymphatic vessels under surgical microscopy, and injecting a mixture of lead oxide into the lymphatic vessels using microinjection technique to visualize the fine lymphatic vessels. After multiple infusions, dissections, photography, and X-ray imaging, the morphology, distribution, drainage direction, anatomical relationship with superficial veins, and types of degenerated lymph nodes of the human trunk, superficial lymphatic vessels, could be presented in detail and could be studied and preserved in the form of intuitive color photos and X-rays (Pan, 2013; Pan, 2014; Pan 2016; Pan, 2017; Ma, 2021). Subsequent minor technological improvements could slow down the decay rate of fresh specimens during perfusion or be used to prepare human lymphatic vessel specimens. The application of these new technologies enabled further research on the human lymphatic system.

Anatomical Characteristics of Lymphatic Vessel Distribution and Drainage in the Thigh

Using this new technology, a detailed study on the distribution of superficial lymphatic vessels/nodes in the lower limbs have been reported (Pan, 2013). The literature has shown that an average of 29 (ranging from 27 to 31) lymphatic vessels could be detected in the subcutaneous tissue of the thigh, with an average diameter of 0.8 mm (ranging from 0.1 to 1.6 mm) (Figure 2). There were abundant lymphatic valves in the lumen, with valve intervals of about 2 to 3 mm (Figure 3). They could be divided into three groups:

1. Anterior Group:

Collecting lymphatic vessels originated from the lateral side of the thigh and traveled inwardly and upwardly within the subcutaneous tissue in the anterior area of the thigh, merging into the inguinal lateral group lymph nodes (vessels were marked in green in Figure 2).

2. Medial Group:

Collecting lymphatic vessels ascended from the medial side of the knee, accompanied by the great saphenous vein and it branches in the subcutaneous

tissue of the anteromedial thigh and converged into the central group of inguinal lymph nodes (vessels were marked in yellow in Figure 2).

3. Posterior Group:

Collecting lymphatic vessels originated from the posterior side of the thigh and traveled medially, forwardly and upwardly within the subcutaneous tissue in this area, merging into the inguinal lymph nodes (vessels were marked in blue in Figure 2).

These lymphatic vessels sometimes branched, or merged after branching, or anastomosed with adjacent lymphatic vessels, or crossed over to each other. Before entering the lymph nodes, the collecting lymphatic vessels could be divided into multiple small branches (Figure 3).

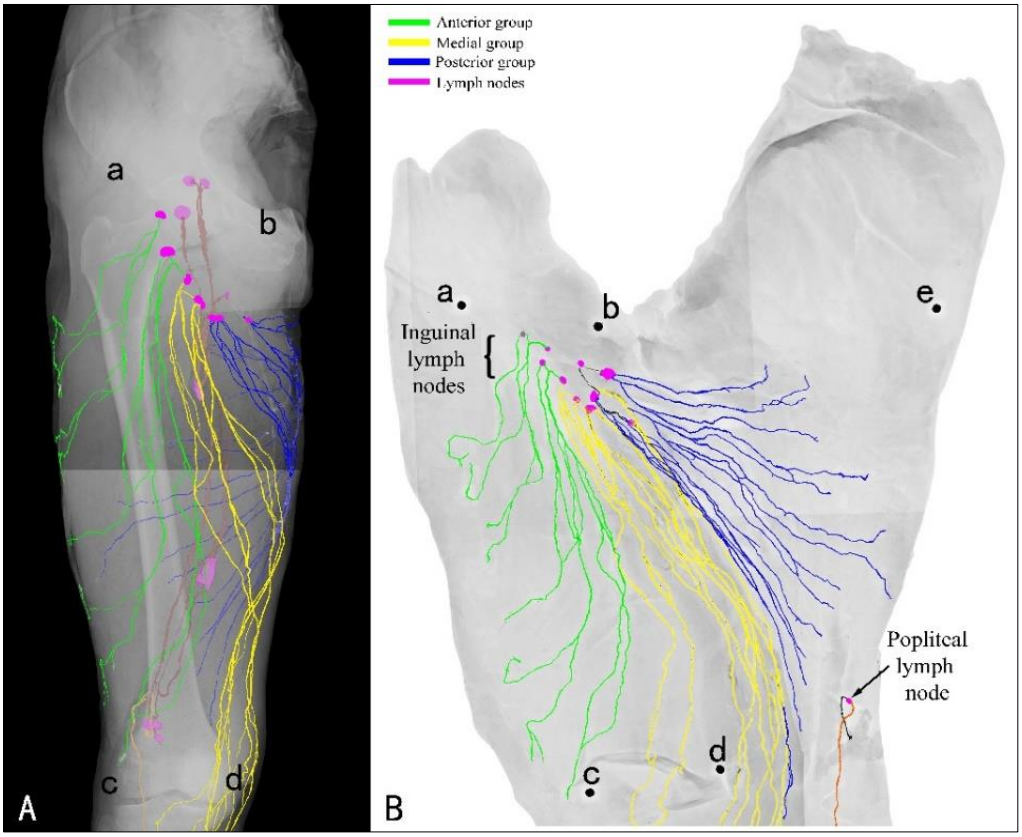

Figure 2: Superficial lymphatic distribution of the human thigh (after perfusion with lead oxide mixture). A: Anteroposterior position of X-ray; B: Flat position of thigh skin. a: Anterosuperior iliac spine; b: Pubic tubercle; c: Lateral epicondyle; d: Medial epicondyle

Figure 3: The superficial lymphatic vessels of the human thigh converge into inguinal lymph nodes (after perfusion with barium sulfate mixture). LN: inguinal lymph nodes; GSV: great saphenous vein

Anatomical Characteristics of Lymphatic Vessel Distribution and Drainage in the Anterior Lateral Thigh Flap

Comparing the anatomical characteristics of the design in the anterior lateral thigh flap (Xu, 1984), it could be seen from Figures 2A and 4A that the collecting lymphatic vessels contained in the anterior lateral thigh flap were mainly of the anterior thigh group, which were composed of an average of 9 (ranging from 8 to 10) lymphatic vessels. The average diameter of the middle segment of each lymphatic vessel is 0.7 mm (ranging from 0.3 to 1.2 mm) (Figure 4B). They meandered between the dermis and deep fascia. Distribution characteristics of vessels were not only described in the previous paragraph, but also had the following features: The inner part of the anterior thigh group of lymphatic vessels in the lower were longer, which first travelled inwardly and upwardly, and then ran upwardly; The lymphatic vessels in the upper outer region were shorter and ran obliquely towards the upper inner region. They could branch, or merge after branching, or anastomose with adjacent lymphatic vessels, or cross to each other and merge into the lateral lymph nodes at the inguinal region.

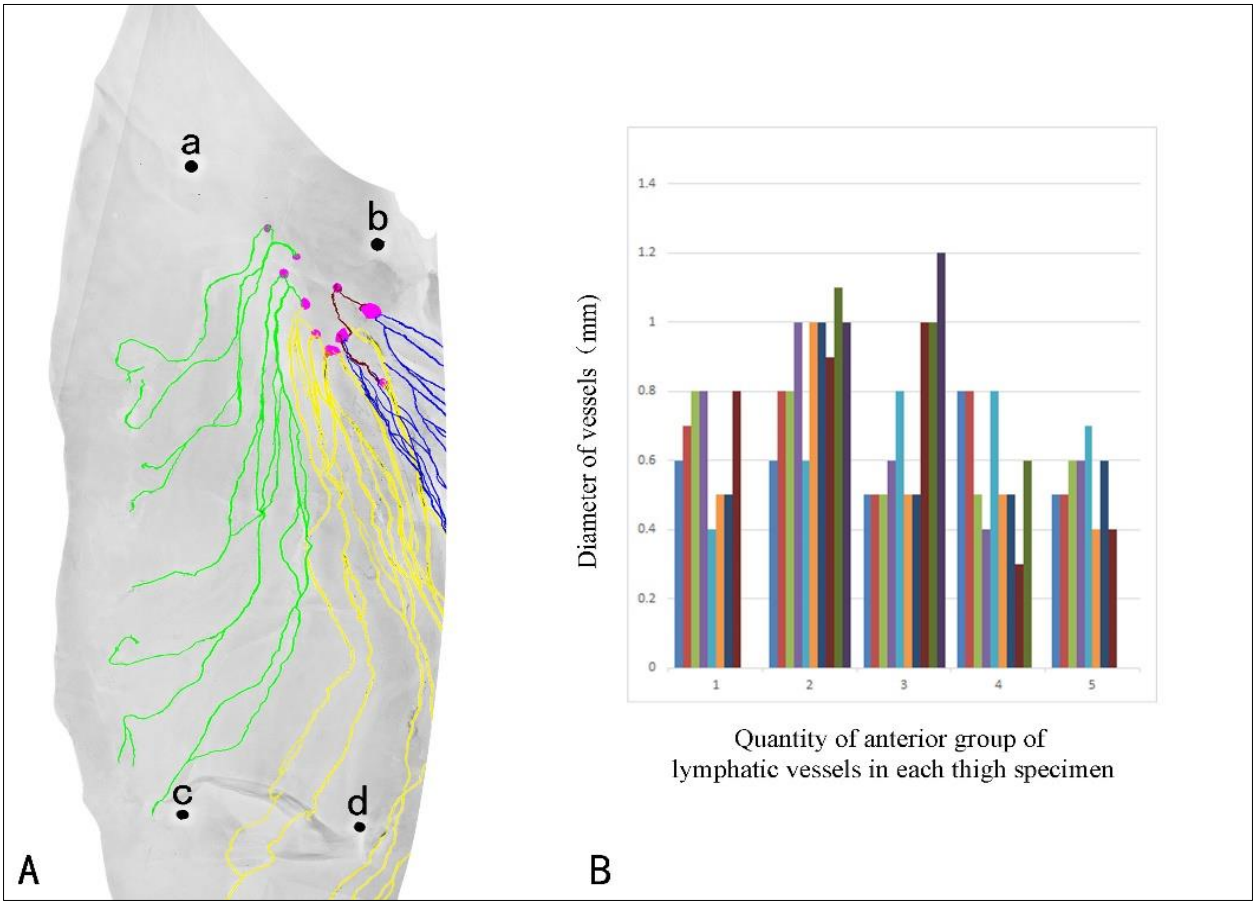

Figure 4: Distribution and drainage of superficial lymphatic vessels in the anterior thigh. A: Distribution and drainage of superficial lymphatic vessels in the anterior group (green); B: Statistical chart of the number and diameter of superficial lymphatic vessels in the anterior group

Clinical Significance

Surgical procedures of the lymphatovenous anastomosis, vascular lymph node flap transplantation and other operations were frequently used to treat iatrogenic lymphedema of upper limbs, a complication of breast cancer surgery (Neligan, 2015; Liu, 2021). Recent literature has shown that the use of vascularized lymphatic flap transplantation for the treatment of the iatrogenic lymphedema of upper limbs could also achieve therapeutic effects similar to those of vascularized lymph node flap transplantation (Chen, 2019). We believe that there is a rich distribution of collecting lymphatic vessels in the area of the anterior lateral thigh flap, which is also the donor site obtained from the vascularized lymphatic vessel flap.

Summary

A detailed understanding of the lymphatic vessel distribution and drainage characteristics of this skin flap could provide some new anatomical information for relevant clinical, teaching, and scientific research. Especially, when considering the use of this flap as a lymphatic vessel flap for the treatment of secondary lymphedema in the upper limbs.

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