Lymphatic Drainage of the Superficial Tissues of the Head and Neck: Anatomical Study and Clinical Implications

Wei-Ren Pan, M.D.
Hiroo Suami, M.D., Ph.D.
G. Ian Taylor, A.O., M.D.

Melbourne, Victoria, Australia

Background: Current knowledge of the anatomy of the lymphatic system does not match or explain some of the unexpected clinical and lymphoscintigraphic findings seen in head and neck cancer patients. There is the need, therefore, to remap the lymphatic network of the superficial tissues of the head and neck region.

Methods: Eighteen halves of the superficial tissues of the head and neck from nine fresh human cadavers were studied over a 20-month period using a mixture of 6% hydrogen peroxide (Orion Laboratories, Balcatta, Australia) with and without India ink to detect the lymphatic vessels and then inject them with a radiopaque lead oxide mixture (AJAX Chemicals, Sydney, Australia).

Results: These unique studies showed (1) lymph capillaries arising from the skin and the galea layers draining sequentially into precollecting lymph vessels, collecting lymphatics, and the first-tier lymph nodes; (2) collecting vessels averaging 0.2 mm in diameter with unusual "lymphatic ampullae" structures and inactive lymph nodes observed often along their course; (3) different network patterns between subjects and between sides of the same subject; (4) similar relationships between lymphatic and venous systems; (5) a lymphaticovenous shunt in the occipital region; (6) lymphatics sometimes bypassing the expected nodes to reach sentinel nodes in the root of the neck; and (7) the lymphatics of the anterior neck lying *above* the platysma and coursing horizontally, obliquely, and upward toward the mandible.

Conclusion: A map of the head and neck lymphatics is presented to aid clinicians with the management of trauma and malignancies in the region. (*Plast. Reconstr. Surg.* 121: 1614, 2008.)

The lymphatic system is the least understood aspect of the human anatomy. Current understanding of the pattern of lymphatic channels is based largely on the anatomical studies of Sappey in 1874.[1] Lymph vessels are tiny transparent channels, separate from the blood vessels, that form a network over the entire body. They are concentrated near the skin surface, the lining of the gut, and even the galea aponeurosis in the head and neck, where they collect and transport tissue fluid (lymph), which can contain various toxins and microorganisms to lymph nodes, where the immune response may be initiated to combat these foreign agents.

The lymphatic system plays an important role in human health and disease. In addition to a role in the immune response, the lymphatics are an important means of cancer dissemination. Cancers of the skin, breast, and respiratory and gastrointestinal tracts frequently spread through the network of lymphatic channels that transport cancer cells centrally to regional lymph nodes situated in the neck, armpits, groin, and thoracic and abdominal cavities.

Recent clinical experience in melanoma and breast cancer and our most recent cadaveric re-

From the Jack Brockhoff Reconstructive Plastic Surgery Research Unit, Royal Melbourne Hospital, Department of Anatomy and Cell Biology, University of Melbourne.
Received for publication March 22, 2007; accepted May 22, 2007.

DOI: 10.1097/PRS.0b013e31816aa072

Disclosure: *The authors declare that there is no source of financial or other support or any financial or professional relationships that may pose a competing interest.*

sults have led to a fundamental reevaluation of Sappey's theory.[2,3] It is well known that cancers can recur at distant sites in the absence of lymph nodal involvement, suggesting that disseminating cancer cells can access the circulation without traversing lymph nodes. Therefore, a precise "map" of the anatomical details of the lymphatic pathways of the head and neck becomes an important basis for clinical management of trauma, infection, lymphedema, and cancer.

MATERIALS AND METHODS

The investigation was performed in fresh cadavers. A total of 10 halves of the superficial tissues of the head and neck plus four bilateral anterior neck specimens from nine fresh human cadavers were studied over a 20-month period. The head and neck specimens were disarticulated at different levels of the neck. The skin and subcutaneous tissues were removed with a midline sagittal incision down to and including the outer layer of the deep fascia, thereby including the galea over the skull, the muscles of facial expression, the deep fascia on the temporalis and masseter muscles, the platysma on the anterior neck, and the deep fascia on the posterior neck muscles. There were two main steps with each lymphatic injection: finding the lymph vessels and injecting the lymph vessels.

Finding the Lymph Vessels

First, in two subjects (four halves), a mixture of India ink (Pebeo, Provence, France) and 6% hydrogen peroxide (in a 1:5 ratio) was injected intradermally and subcutaneously in the midline of the scalp. Then, the scalp was removed from the skull. The tissue was examined both macroscopically and microscopically and photographed using a Nikon Coolpix 990 (Nikon Corp., Tokyo, Japan) (Fig. 1).

Second, in the remaining studies, 6% hydrogen peroxide was injected directly into the tissue from the undersurface of the galea. Using a surgical microscope (Zeiss, Oberkochen, Germany), dissection commenced close to the midline. Inflated lymph vessels were found in the subcutaneous tissue. They were distinguished from veins by their wall characteristics and larger number of valves.[4,5]

Injecting the Lymph Vessels

The inflated vessel was injected with a radiopaque suspension of lead oxide and powdered milk using our modified formula[4] and a 30-gauge, 1-inch needle (Precision Glide Needle; Becton

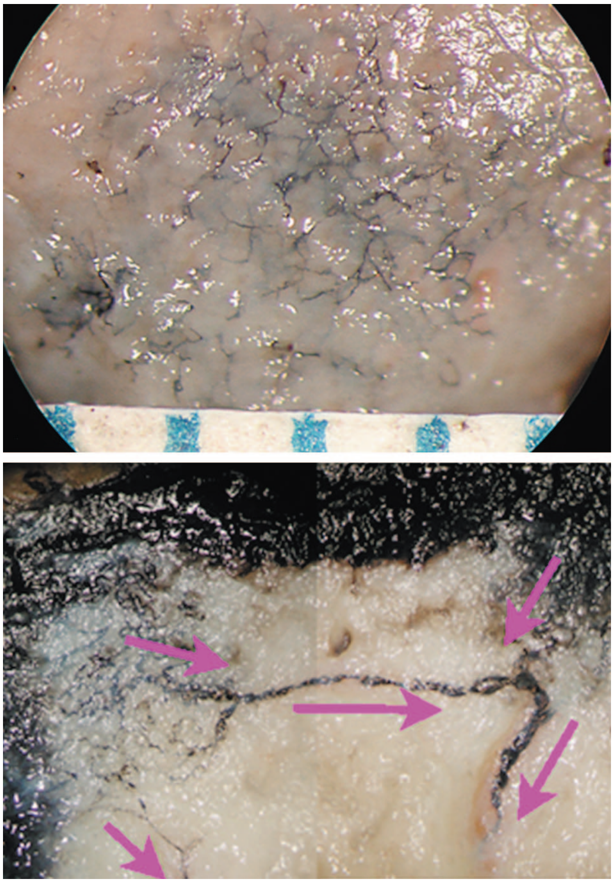

Fig. 1. (*Above*) Lymph capillary network in the dermis filled with the India ink mixture. (*Below*) Lymphatic vessels in the galea layer filled with the India ink mixture.

Dickinson, Franklin Lakes, N.J.) or a premade glass tube needle,[5,6] depending on the size of the lymph vessel. Attached to an extension tube (B. Braun Medical Industries, Penang, Malaysia) connected to a 1-ml syringe fixed on a micromanipulator (UM-3c; Narishige Scientific Instrument Laboratory, Tokyo, Japan), the needle was inserted into the lumen of the vessel and passed through a valve to prevent leakage. The warm suspension in the 1-ml syringe was slowly and gently pulsed into the vessel. Any resistance from the syringe or leakage from the injection point indicated the end of the injection.

After the injection, the specimen was radiographed (Diagnostic Film EB-1; Eastman Kodak, Rochester, N.Y.). It also acted as a guide for the next injection if the vessel had not been filled completely. In these cases, the procedure was repeated at the farthest reaches of the injectant. Each vessel required several injections.

Radiographic settings were as follows: the specimen was placed 1.5 m from the machine.

Amperage of 100 mA and voltage of 58 kV were used with an exposure time of 0.03 seconds. If a lymph capillary network was noticed, which could only have filled by backflow when the perfusion was performed in the collecting vessel, it was dissected under the surgical microscope and transilluminated above a light box (Fig. 2).

We had noted that the venous system also took up the hydrogen peroxide. In one specimen, hydrogen peroxide was injected retrogradely into the main cutaneous veins to create a comparative image of the venous and lymphatic pathways (Fig. 3).[7]

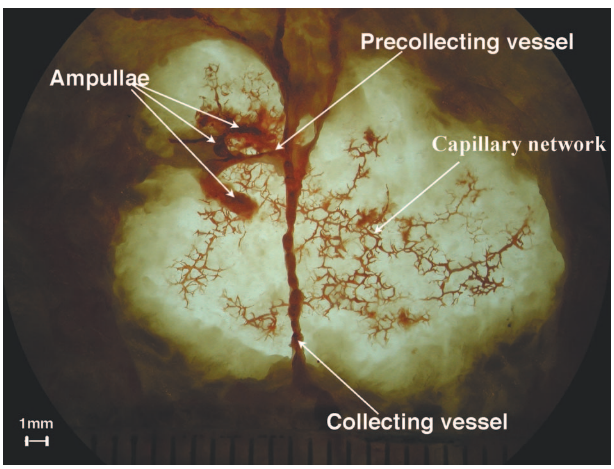

Fig. 2. Transilluminated view of the injected lymphatics from the undersurface of the scalp. Note that the lymph capillaries link to precollecting lymph vessels that drain to collecting lymph vessels and the swollen structures on the precollecting vessels that we have named "lymphatic ampullae."

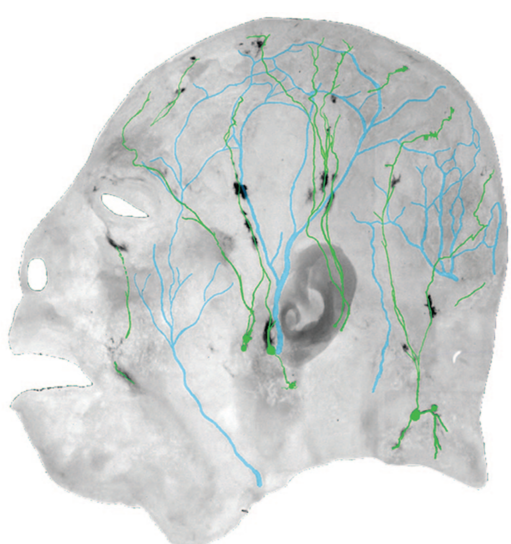

Fig. 3. Tracing of radiograph result. Comparison of lymph vessels (*green*) and veins (*blue*). Note how the main collecting lymphatics bear some relationship to the major veins.

The photographs and radiographs were transferred into a computer (Macintosh G5; Apple Computer, Inc., Cupertino, Calif.). The lymphatic vessels were traced and color coded to match their related first-tier lymph nodes (Fig. 4).

RESULTS

Overview

The lymph capillary vessels originate from both the dermis and the galea layers, converge to the precollecting vessels that run a short distance, and then drain into the lymph collecting vessels that course caudally in the subcutaneous tissue. During their course, the lymph collecting vessels receive precollectors and drain toward their first-tier lymph nodes in the head and neck (Fig. 4).

Distribution of the Lymph Vessels and Nodes

Three groups of lymphatic vessels are represented in the superficial tissue of the head and neck region: the scalp group, the facial group, and the anterior neck group.

Scalp Group

Lymph capillaries. These originate as a fine three-dimensional polygonal network in both the dermis and the galea layers (Figs. 1, 2, and 5). The diameter of these vessels varies, small in the dermis ($<$0.1 mm) and large in the galea layer (sometimes $>$0.2 mm). The wall is very fragile and valves have not been found. They drain into the precollecting lymph vessels that converge toward the lymph collectors coursing in the deep aspect of the subcutaneous tissue.

Precollecting vessels. The diameter of the precollecting lymph vessels varied from 0.1 to 0.3 mm when distended with hydrogen peroxide. A single "swollen" structure was often revealed on the initial segment of the precollecting lymph vessels that we have named a *lymphatic ampulla* (Fig. 2). Two types of precollecting pathways were found to link the lymph capillary network and the lymph collecting vessels. The precollecting vessels that ran *directly* from the capillary network in the dermis or galea to the collecting vessels in the subcutaneous fat were called "direct precollectors" (Figs. 1, 2, and 5). Alternatively, precollecting vessels that arose from the lymph capillary network of the dermis and crossed the subcutaneous tissue, thereby bypassing collecting vessels, to reach the galea network and join its precollectors, were

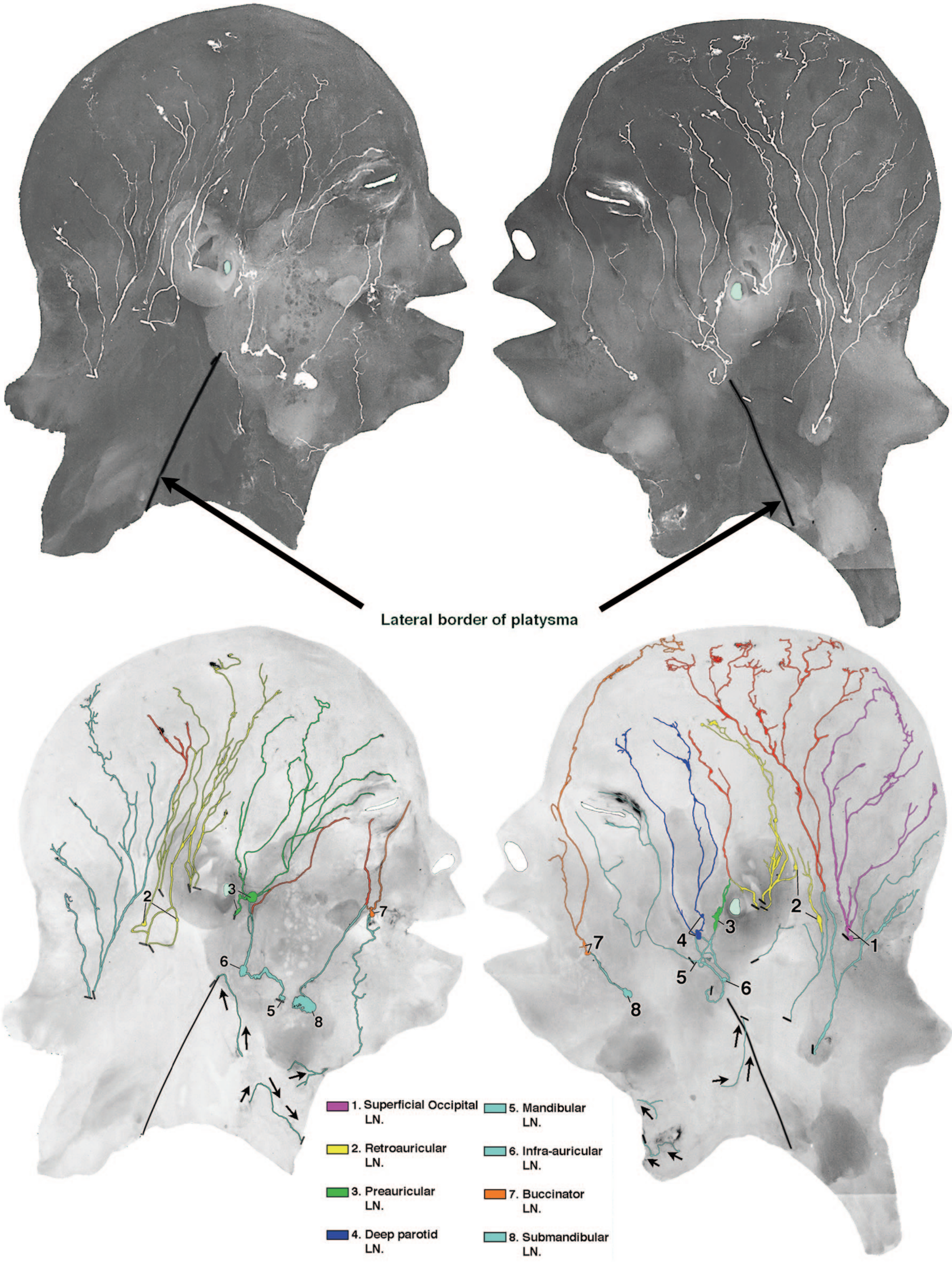

Fig. 4. (*Above*) The radiographs show the distribution of the lymphatics in the superficial tissues of the head and neck of one subject. (*Below*) The lymphatic vessels have been traced and color coded to match their related first-tier lymph nodes that are identified in the chart.

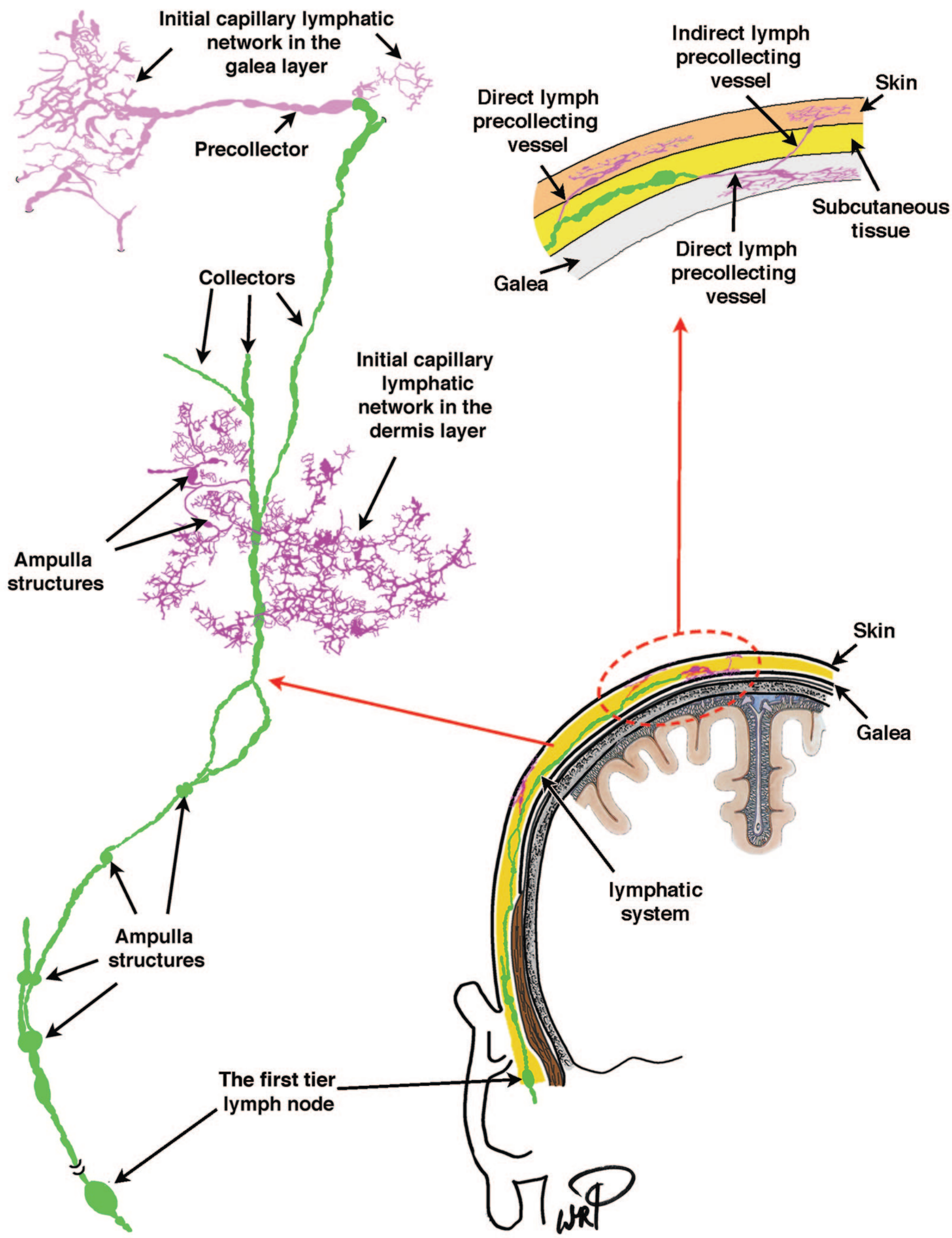

Fig. 5. (*Left* and *below*, *right*) These drawings show the basic lymphatic pathway in the scalp. (*Above*, *right*) The initial capillary lymphatic network originates from both the dermis and galea layers to join a precollecting vessel that runs either directly or indirectly a short distance in both layers before forming a collecting vessel in the subcutaneous fatty layer. Along its course, the collecting vessel divides and converges and may form different shaped lymphatic ampullae before finally reaching the lymph node.

named "indirect precollectors" or "bridge precollectors" (Figs. 5 and 6).

Lymph collecting vessels. The lymph collecting trunks arose from the precollectors approximately 2 cm from the midline and ran obliquely downward and backward to reach their first-tier lymph nodes (Figs. 4 and 5). The lymphatics of each sentinel node sometimes branched, diverged, and converged within their own territory. Sometimes, they anastomosed with neighboring vessels or crossed them. When they met blood vessels and nerves, they passed either superficially or on their deep side.

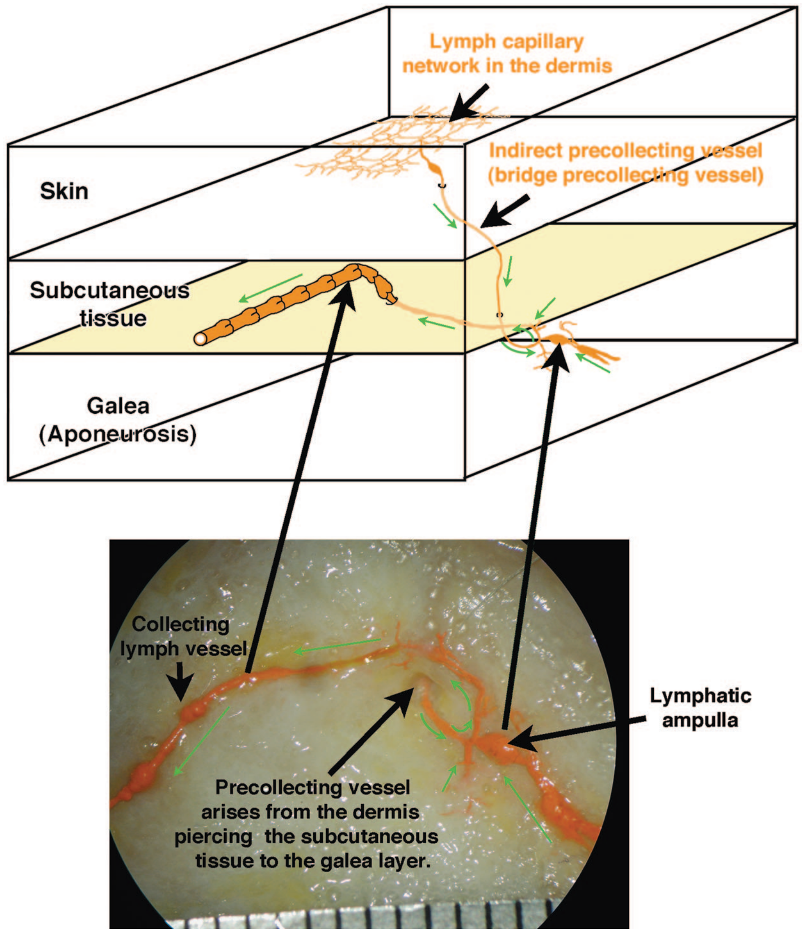

Fig. 6. (*Above*) The lymph capillary network of the skin is shown with an indirect precollecting lymphatic vessel that crosses the subcutaneous tissue and runs toward the galea, where it converges with the other precollector(s) that drain into the lymph collecting vessel shown in the diagram. (*Below*) The lymphatics are viewed from the undersurface of the galea.

The diameters of the lymph collecting vessels average 0.2 mm when distended with hydrogen peroxide. Once again, swollen structures (lymphatic ampullae) of different sizes and shapes were seen along the vessels. Cross-section shows that these structures have a hollow center that filled with lead oxide (Figs. 5 through 7). They appeared in some form in the scalp of every specimen.

The lymphatic pathway patterns differ from person to person and are even asymmetrical on each side of the same body. The number of lymph vessels, their origins, their course, their relationships with the other vessels, and the terminal (sentinel) lymph nodes of the frontal, parietal, and occipital groups are shown in Figure 4.

Facial Group

The lymph collecting vessels were sparse in this region. The diameter of these vessels was approximately 0.3 mm when distended with hydrogen peroxide near their sentinel nodes. They took their origin from the lymph capillary network of the upper and lower eyelids, both the inner and outer canthi, the middle of the lower eyelid, the side of the nose, the side of the mouth, and the chin. These vessels ran mostly obliquely downward and backward in the subcutaneous tissue. Like the scalp, they divided and converged and sometimes anastomosed with the neighboring vessels (Fig. 4).

Anterior Neck Group

The lymph vessels of the superficial tissue of the anterior neck run in the subcutaneous layer above the platysma muscle. The diameter of this group of lymph collecting vessels was approximately 0.2 mm when distended with hydrogen peroxide. They ran upward, horizontally, or obliquely, and pierced the platysma to reach the

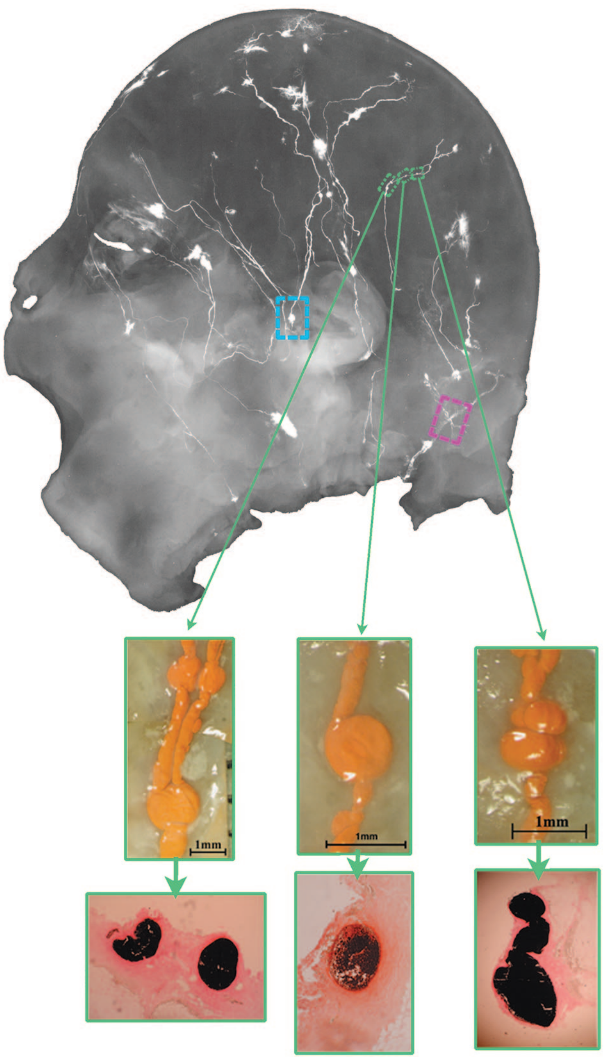

Fig. 7. (*Above*) Magnified images of three different shaped lead oxide–injected lymphatic ampulla structures found on one lymphatic collecting vessel. (*Below*) Histologic sections.

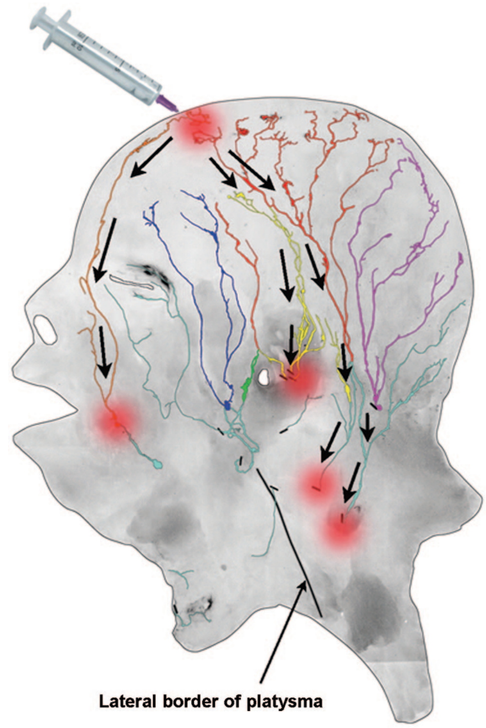

Fig. 8. This image shows how an injection site on the frontoparietal point of the scalp in one of our studies could pass to either the buccinator lymph node after crossing the forehead or the retroauricular and cervical lymph nodes by crossing the midcoronal line or all three lymph nodes. Our study confirms lymphoscintigraphy (see Uren, R. F., Thompson, J. F., and Howman-Giles, R. B. *Lymphatic Drainage of the Skin and Breast.* Australia: Harwood Academic Publishers, 1999, Pp. 110–118; and Thompson, J. F., Morton, D. L., and Kroon, B. B. R. *Textbook of Melanoma.* London: Martin Dunitz, 2004, Pp. 353–358).

first-tier lymph nodes near the midline, submandibular line, and lateral border of the platysma (Figs. 4, 8, and 9).

Inactive Lymph Nodes

Compared with the normal solid lymph node,[8] the buccinator, preauricular, retroauricular, and superficial occipital lymph nodes showed a transparent structure. These transparent nodes were very easily damaged when they were not inflated or injected. Under the microscope, multiple lymphatic vessels were found in these nodes and on histologic examination were found to be a lymphatic coil that occupied most of the node's lumen (Fig. 10).

Lymphaticovenous Shunt

During the study, one lymphaticovenous anastomosis site was found in the occipital region (Fig. 11).

Comparison of Lymph Vessels and Veins

Our previous radiographic venous studies of the head and neck[7] showed that most veins have no valves in this region. The diameter of the veins increases in size beyond the midline.

In contrast, the lymphatic collecting vessels have a uniform diameter and many valves in the lumen. They may or may not accompany the major veins. They course with the veins over both their superficial and deep surfaces (Fig. 3).

Bypass Routes

We found that the lymph collecting vessels in the head and neck do not always enter the first-tier

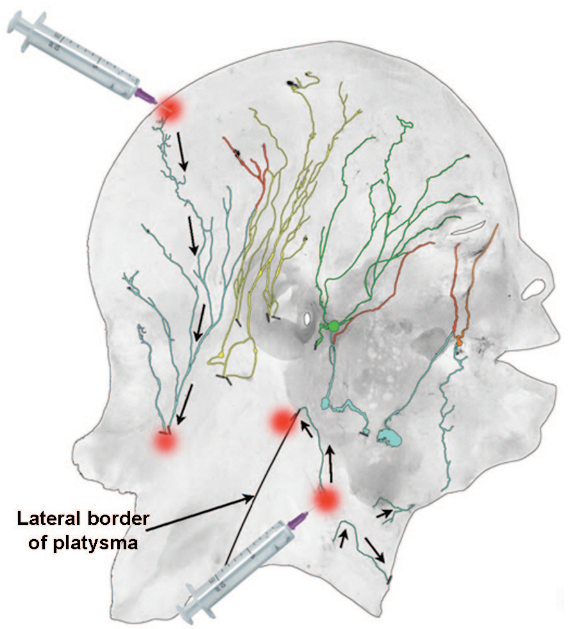

Fig. 9. This image demonstrates how an injection in the occipital area of the lymph drainage in one of our studies could bypass the first-tier node (occipital lymph nodes) to reach nodes lower in the neck. It shows also how an isotope injection in the anterior neck could pass upward to reach nodes near the lower jaw along lymphatics coursing superficial to the platysma. This pathway helps explain some of the unexpected clinical findings (see Uren, R. F., Thompson, J. F., and Howman-Giles, R. B. *Lymphatic Drainage of the Skin and Breast*. Australia: Harwood Academic Publishers, 1999, Pp. 110–118; and Thompson, J. F., Morton, D. L., and Kroon, B. B. R. *Textbook of Melanoma*. London: Martin Dunitz, 2004, Pp. 353–358).

lymph nodes but sometimes bypass them. This occurs in three ways (Fig. 4, 8, and 9): (1) the single vessel enters the next-tier lymph node directly; (2) the single vessel gives two branches (one enters the first-tier lymph node and the other branch bypasses the node to eminent nodes); and (3) the vessel joins with a neighboring vessel, bypassing the first-tier nodes and entering the eminent nodes.

DISCUSSION

Sappey's lymphatic results[1] led the field for more than 100 years. In general, our results agree with his. However, we have made new findings, and the differences in our results may be attributable to the different ages of the cadavers studied. Our study shows, in addition to the macroscopic appearance, the microscopic, radiographic, and photographic images of the lymphatic structures of the superficial tissue of the head and neck.

Considerable experience and microsurgical expertise was required to identify and inject each lymphatic. Each vessel required multiple injections to trace its course, which is why each subject took 6 to 8 weeks to complete. Although we froze or cooled the tissue between each examination, it literally became a race between dissection and putrefaction. Nevertheless, there have been several new revelations.

1. This is the first radiographic record of the superficial lymphatics of the head and neck.
2. It is the first time that the lymph capillary network has been found and recorded in the galea layer of the scalp.
3. It is the first time that "lymphatic ampullae" structures on the lymph vessels have been found and described.
4. It is also the first time that the lymph vessels have been described in the anterior neck above the platysma, with some draining upward toward the mandible.

Other incidental findings, such as the lymphatic bypass routes and the lymphaticovenous shunt, all add to our knowledge and have an impact on the management of head and neck oncology. This study confirms the virtually unpredictable nature of the superficial lymphatic drainage of the head and neck. We would like to emphasize certain points.

Basic Lymphatic Unit of the Scalp

Each unit contains the lymph capillary network, the precollecting vessels, the collecting vessels, and the first-tier lymph node (Fig. 5). Ampullae structures appear on the precollecting and collecting vessels (Figs. 2 and 5 through 7).

Lymph Capillary Network

The lymph capillary vessels originating from the dermis (the outer network) have an important role in the immune defense mechanism that has been well described.[9,10] Those found in the galea layer by us may have a role similar to those in the skin, as the scalp is a common site of trauma. These vessels are thin walled and are shaped irregularly. Sometimes, they appear constricted and at other times dilated. They branch abundantly and anastomose freely to form a rich avalvular network.

Lymphatic Ampullae

There are only three dilated lymph vessel structures described in the human lymph system. They are the cisterna chyli and ampullae near where the thoracic duct and the right lymph sys-

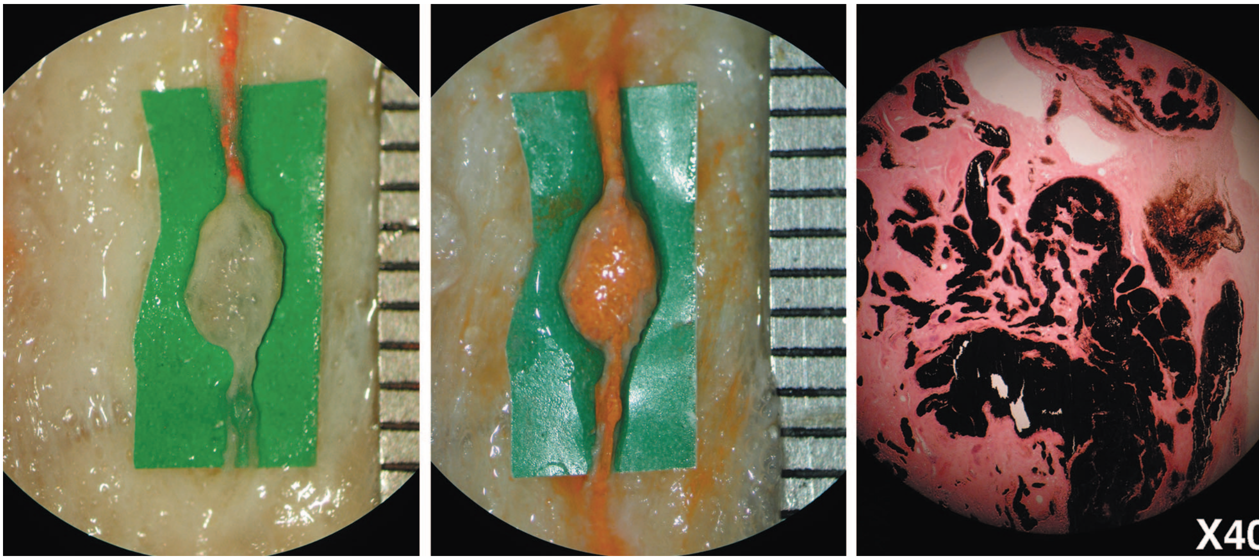

Fig. 10. These images are magnified from the “blue box” of the radiograph in Figure 7. The row of images shows inactive (preauricular) lymph node: (*left*) the “transparent” nature; (*center*) the node filled with lead oxide mixture; and (*right*) a histologic section showing the lymphatic coil occupying most of the lumen.

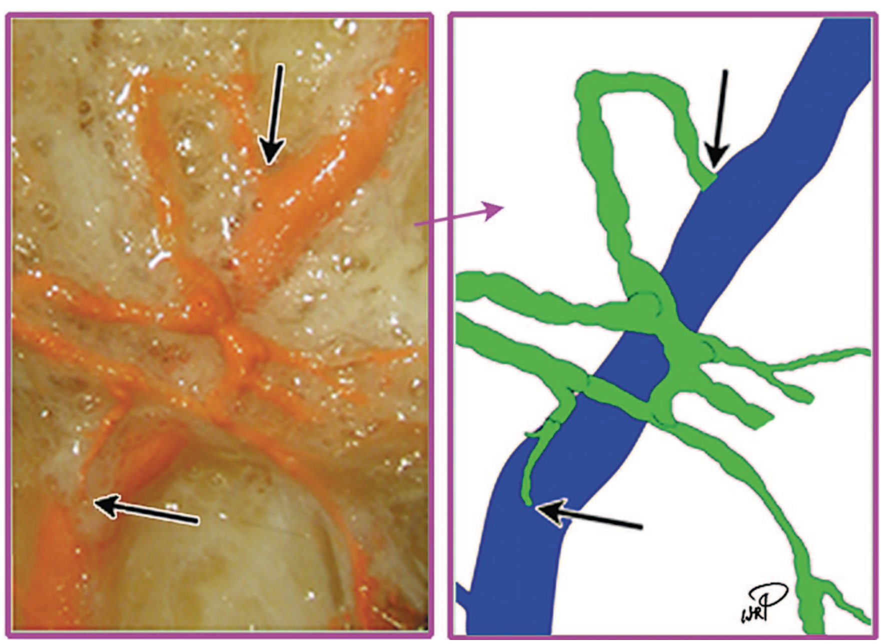

Fig. 11. These images are magnified from the “purple box” in the radiograph in Figure 7. The photograph shows the lymphaticovenous anastomoses site in the occipital area (*black arrows*) and confirms the clinical findings of Wallace et al. (Wallace, S., Jackson, L., Dodd, G. D., and Greening, R. R. Lymphatic dynamics in certain abnormal states. *Am. J. Roentgenol. Radium Ther. Nucl. Med.* 91: 1199, 1964). (*Right*) A schematic drawing.

tem enter the venous system.[11,12] However, similar but smaller dilated structures were found at the origin of the precollecting vessels and along the course of the collecting vessels. These lymphatic ampullae were found in different shapes and sizes (Figs. 2 and 5 through 7) and appeared in every specimen. Histologic section shows that the structures are hollow and filled with lead oxide (Fig. 7). Their function is unknown.

Precollecting Lymph Vessels

Two types of precollecting vessels have been described. These are the *indirect* precollectors that bridge between the lymph capillary networks in the dermis and those in the galea, and the *direct* precollectors that pass immediately from the capillary network in the dermis or galea to the collecting vessels (Figs. 5 and 6). It is noteworthy that there was backflow of the lead oxide mixture from the precollectors to the lymph capillaries in the scalp in each of our studies, although we have been unable to obtain this in our studies of the upper extremity[6] unless there was obstruction of the collecting lymphatics.[13]

Collecting Lymph Vessels

Compared with Sappey's work,[1] our studies show different patterns in individual specimens, whereas his results provided a composite of several studies.

Inactive Lymph Nodes

We used cadavers aged between 74 and 96 years for this study and found that the buccinator, preauricular, retroauricular, and superficial occipital lymph nodes have a transparent nature (Fig. 10) because of senile involution.[14] These may be the lymph nodes referred to as "inactive" by some pathologists.[8] Földi et al. also reported that these nodes are in a degenerative state because of senile involution and could be reactivated in the event of infection or metastasis.[14] We agree with this theory but disagree that the senile involution predominately affects the medulla and the cortex remains unaffected. Our results show that all nodes contain coils of lymphatics, and pathologic section shows no cortex or medulla.

Sentinel Lymph Node Biopsy

The "sentinel node" concept was first introduced by Gould et al.[15] In 1992, Morton et al. reported an invasive method of intraoperative lymphatic mapping for treating early-stage melanoma, and in 1993 Alex and Krag introduced a noninvasive technique using gamma-probe localization of lymph nodes as they attempted to reduce the morbidity that follows regional lymph node ablation, especially for melanoma and breast cancer.[16–18] Treatment of melanomas in the head and neck is inherently problematic. It was found that lymphatic flow patterns of lymphoscintigraphy[2,3] were often discordant with previous clinical prediction[19,20] based on Sappey's works. Uren et al. and Thompson et al., using lymphoscintigraphiv images, found the false-negative result to be as high as 34 percent. This figure indicates that the surgeon will fail to remove nodes potentially containing metastatic disease in one of three patients.[2,3]

Although our studies demonstrate static anatomical images rather than the dynamic physiologic state, they update Sappey's results[1] and help explain the unexpected lymphoscintigraphic findings (Figs. 8 and 9). The following points should always be of concern for the surgeon when they perform lymphoscintigraphy and are emphasized by Thompson et al. and Uren et al.[2,3]

1. An injection site at the frontoparietal junction of the scalp may go to either or all of (a) the buccinator lymph nodes by crossing the forehead, and (b) the retroauricular and cervical lymph nodes by crossing the midcoronal line. We have shown that an injection at this site may reach anatomically two or more sentinel nodes (Fig. 8).
2. An injection can bypass the expected first-tier node. This can occur in both the face and the scalp, as seen in our studies (Fig. 9).
3. Lymphatic pathways of the anterior neck lying above the platysma course upward, horizontally, and obliquely, as seen in our studies, which explains the clinical and lymphoscintigraphic findings in this region (Figs. 4 and 9).

Lymphaticovenous Shunt

One lymphaticovenous anastomoses site was found. The efferent lymph vessels of the superficial occipital lymph nodes formed a lymphatic network at the occipital and neck junction. From this network, two vessels emerged to communicate with a superficial occipital vein in the subcutaneous layer (Fig. 11). This confirmed the clinical findings described by Wallace et al. in 1964.[21] It should be noted, therefore, that this anastomosis may provide a systemic route for metastatic disease.

CONCLUSIONS

The lymphatic territories of the superficial tissues of the head and neck, with their first-tier lymph nodes, have been mapped and found to vary between individuals and within the same individual. A rich avalvular lymph capillary network exists in the skin and, as we have found, in the galea of the scalp that connects anatomically adjacent lymph territories. We report several new discoveries that help explain some of the unexpected findings seen on lymphoscintigraphy of the region. This is a static anatomical study accurately revealing the superficial lymphatic pathways and the possibilities for clinical management.

Wei-Ren Pan, M.D.
Room E533, Medical Building
Department of Anatomy and Cell Biology
University of Melbourne
Grattan Street
Parkville 3050, Victoria, Australia
w.pan@unimelb.edu.au

ACKNOWLEDGMENTS

The authors are indebted to the Jack Brockhoff Foundation, the Colonial Foundation, and the National Health and Medical Research Foundation for funding this research; the Royal Melbourne Hospital, the Sydney Melanoma Unit at the Sydney Cancer Centre, and the Department of Anatomy and Cell Biology at the University of Melbourne for continuous support; and Prue Dodwell for help with the preparation of the article.

REFERENCES

1. Sappey, P. C. *Anatomie, Physiologie, Pathologie des vaisseaux lymphatiques.* Paris: Adrien Delahaye, 1874.
2. Uren, R. F., Thompson, J. F., and Howman-Giles, R. B. *Lymphatic Drainage of the Skin and Breast.* Australia: Harwood Academic Publishers, 1999. Pp. 110–118.
3. Thompson, J. F., Morton, D. L., and Kroon, B. B. R. *Textbook of Melanoma.* London: Martin Dunitz, 2004. Pp. 353–358.
4. Suami, H., Taylor, G. I., and Pan, W.-R. A new radiographic cadaver injection technique for investigating the lymphatic system. *Plast. Reconstr. Surg.* 115: 2007, 2005.
5. Suami, H., Taylor, G. I., O'Neill, J. K., and Pan, W.-R. Refinements of the radiographic cadaver injection technique for investigating minute lymphatic vessels. *Plast. Reconstr. Surg.* 120: 61, 2007.
6. Suami, H., Taylor, G. I., and Pan, W.-R. The lymphatic territories of the upper limb: Anatomical study and clinical implications. *Plast. Reconstr. Surg.* 119: 1813, 2007.
7. Taylor, G. I., Caddy, C. M., Watterson, P. A., and Crock, J. G. The venous territories (venosomes) of the human body: Experimental study and clinical applications. *Plast. Reconstr. Surg.* 86: 185, 1990.
8. Young, B., and Heath, J. W. *Wheater's Functional Histology: A Text and Colour Atlas,* 4th Ed. Edinburgh: Churchill Livingstone, 2000. P. 206.
9. Cowdry, E. V. *A Textbook of Histology.* Philadelphia: Lea & Febiger, 1950. Pp. 172–174.
10. Drinker, C. K., and Yoffey, J. M. *Lymphatics, Lymph, and Lymphoid Tissue.* Cambridge, Mass.: Harvard University Press, 1941. Pp. 286–290.
11. Rouvière, H. *Anatomy of the Human Lymphatic System.* Ann Arbor, Mich.: Edwards Brothers, 1938. Pp. 5–33.
12. Moore, K. L. *Clinically Oriented Anatomy,* 3rd Ed. Baltimore: Williams & Wilkins, 1992. P. 669.
13. Suami, H., Pan, W.-R., and Taylor, G. I. Changes in the lymph structure of the upper limb after axillary dissection: Radiographic and anatomical study in a human cadaver. *Plast. Reconstr. Surg.* 120: 982, 2007.
14. Földi, M., Földi, E., and Kubik, S. (Eds.). *Textbook of Lymphology.* San Francisco: Urban & Fischer, 2003. Pp. 34–50.
15. Gould, E. A., Winship, T., Philbin, P. H., and Kerr, H. H. Observation on a "sentinel node" in cancer of the parotid. *Cancer* 13: 77, 1960.
16. Morton, D. L., Wen, D.-R., Wong, J. H., et al. Technical details of intraoperative lymphatic mapping for early stage melanoma. *Arch. Surg.* 127: 392, 1992.
17. Alex, J. C., and Krag, D. N. Gamma-probe guided localization of lymph nodes. *Surg. Oncol.* 2: 137, 1993.
18. Krag, D. N., Weaver, D. L., Alex, J. C., and Fairbank, J. T. Surgical resection and radio localization of the sentinel lymph node in breast cancer using a gamma probe. *Surg. Oncol.* 2: 335, 1993.
19. Robbins, K. T., Medina, J. E., Wolfe, G. T., et al. Standardizing neck dissection terminology: Official report of academy's committee for head and neck surgery and oncology. *Arch. Otolaryngol. Head Neck Surg.* 119: 601, 1991.
20. O'Brien, C. J., Petersen-Schaefer, K., Ruark, D., et al. Radical, modified and selective neck dissection for cutaneous malignant melanoma. *Head Neck* 17: 232, 1995.
21. Wallace, S., Jackson, L., Dodd, G. D., and Greening, R. R. Lymphatic dynamics in certain abnormal states. *Am. J. Roentgenol. Radium Ther. Nucl. Med.* 91: 1199, 1964.