Defining the Lymphatic System of the Anterior Abdominal Wall: An Anatomical Study

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Background: Studies describing recent abdominoplasty modifications have reported a decreased incidence of seroma, attributed to preservation of abdominal lymphatics. However, there are limited anatomical data to support this hypothesis. The authors sought to characterize the lymphatic architecture of the abdominal wall and provide a conceptual basis for further refinement of abdominoplasty techniques.

Methods: Fifteen tissue samples from five patients undergoing abdominoplasty were sectioned and analyzed. Slides were stained with hematoxylin and eosin, CD31, and D2-40 and assessed by a pathologist and a plastic surgeon for the presence and number of lymphatics. Results were reported as mean percentage of lymphatic-specific antibody per analyzed area.

Results: Lymphatic vessels were observed in the dermis, superficial fascia, and loose areolar tissue but not in deep or superficial fat. The highest concentration was in the dermis (mean, 82.6 percent; range, 69 to 89.2 percent). The Scarpa fascia contained 9.4 percent of lymphatics (range, 7.0 to 11.4 percent), whereas the loose areolar tissue at the specimen base contained an average of 7.9 percent (range, 2.6 to 19.5 percent). These lymphatics were consistently located in the deepest third, with the Scarpa fascia lying an average of 34 percent of the total tissue thickness above muscle fascia. Lymphatic prevalence did not increase in specimens near the superficial epigastric vessels.

Conclusions: Abdominoplasty flap lymphatics are most common in the dermis, with a significant proportion (approximately 17 percent) also appearing near fascial layers. This confirms the presence of deep lymphatic channels that could potentially be preserved during abdominoplasty or lipoabdominoplasty. (*Plast. Reconstr. Surg.* 135: 1027, 2015.)

Lipoabdominoplasty has grown in popularity in recent years as surgeons have sought to decrease complication rates while still improving abdominal contour. Various techniques have included selective skin excision and abdominal wall liposuction to preserve deeper structures presumed to contain blood vessels, nerves, and lymphatics.[1–8] However, although the literature on clinical outcomes of lipoabdominoplasty has grown, there is still a paucity of anatomical data to support the hypotheses on which it is based. Previous studies have suggested that limited epigastric undermining does preserve arterial perforators.[3] Relatively little is known, however, regarding the distribution of abdominal lymphatics.

The objective of this study was thus to explore the lymphatic architecture of the abdominal wall to understand whether selective liposuction rather than traditional flap elevation could plausibly contribute to better preservation of lymphatics. We also sought to determine whether lymphatic vessels run in proximity to anatomical landmarks of the abdominal wall that could be easily defined in the clinical setting. This information may provide the basis for further refinements in abdominal wall contouring techniques.

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PATIENTS AND METHODS

Fifteen abdominal wall samples from five patients undergoing fleur-de-lis abdominoplasty were analyzed following institutional review board approval. After the abdominal pannus was excised, tissue samples were sectioned from the discarded abdominal tissues, fixed in 4% buffered formaldehyde, embedded in paraffin, and stained with hematoxylin and eosin. Samples were obtained from three locations: one upper abdominal sample was taken 4 cm cephalad to the umbilicus and two samples were harvested 2 cm from the midline on the lower abdomen. Four additional samples were harvested that included the superficial inferior epigastric vein to assess whether lymphatic quantity was increased by proximity to the superficial inferior epigastric vein.

Immunostaining Procedures

A double immunostaining technique was carried out using a commercial antibody against CD31, a cytoplasmic panendothelial marker (clone JC/70A; Neomarkers, Inc., Fremont, Calif.), and by D2-40, a new and highly sensitive lymphatic marker useful for distinguishing lymphatics from other vessels.[9] All slides were reviewed simultaneously by a pathologist and a plastic surgeon using a multihead microscope and 10× loupe magnification. Photographs were taken with a digital camera and exposure was adjusted post hoc to optimize visibility. Lymphatics were counted by anatomical layer, including the skin (upper and lower dermal complexes), superficial fat, superficial fascial system, deep fat, and loose areolar tissue/deep fascia. The width and the thickness of the anatomical layers from the lower tissue margins were measured in millimeters and the data were tabulated. The ratio of lymphatic density of the fascia layers (superficial fascia and loose areolar tissue) to the number of lymphatics in all layers was calculated and compared between patients.

RESULTS

Double staining disclosed a clear differential pattern when comparing vascular with lymphatic vessels: both types of vessels showed endothelial cell cytoplasm stained with fast-red (CD-31), whereas only lymphatic type vessels demonstrated endothelial cell nuclei stained with brown D2-40. Lymphatic vessels were observed in the dermis, superficial fascia, and loose areolar tissue.

The highest concentration of lymphatics was in the dermis, with a mean of 82.6 ± 11.8 percent of the total lymphatic volume per specimen (range, 69 to 89.2 percent). The Scarpa fascia layer had a concentration of 9.4 ± 1.9 percent (range, 7.0 to 11.4 percent). Lymphatics in this area were found to accompany adjacent veins and arteries (Fig. 1). The loose areolar tissue at the base of the specimen contained an average of 7.9 ± 6.7 percent of the lymphatics (range, 2.6 to 19.5 percent). These two layers combined contained up to 17.4 ± 7.9 percent (range, 10.9 to 30.9 percent) of the abdominal wall lymphatics. These deep lymphatics were consistently located in the deepest one-third of the abdominal wall, with a mean distance from the muscle fascia of 34.2 ± 2.1 percent of the total thickness (range, 30.2 to 37.2 percent) (Fig. 2 and Table 1).

Although neither the deep nor the superficial subcutaneous fat contained lymphatics, blood vessels were common (Fig. 3). There was no correlation between the patient's current or maximum body

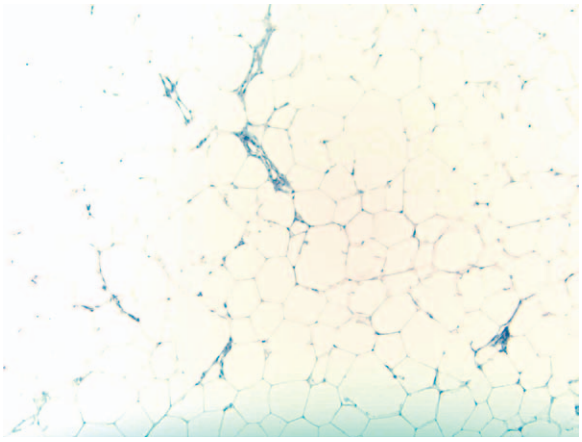

Fig. 1. No lymphatic vessels were observed in the superficial or deep fat layers (D2-40).

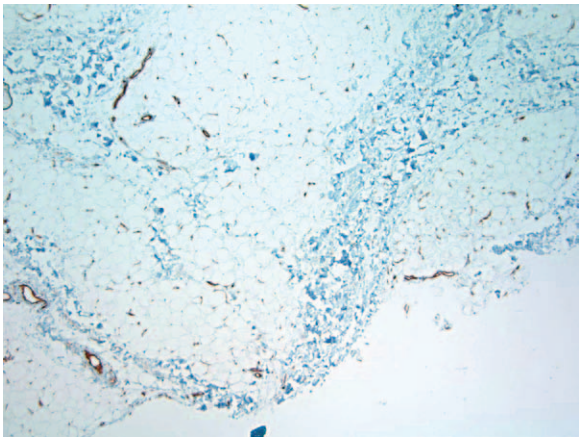

Fig. 2. Lymphatic vessels are also observed in the loose areolar tissue (D2-40).

Table 1. Measurements of Lymphatic Density in the Deep Abdominal Wall

Patient	BMI	Depth of Scarpa Fascia (%)*	Density of Scarpa Fascia Lymphatics (%)	Density of Areolar Tissue Lymphatics (%)	Deep Abdominal Lymphatics (Scarpa Fascia plus areolar tissue) (%)
1	28.3	36.0	8.3	2.55	10.85
2	34	33.9	11.42	19.49	30.91
3	28.7	30.2	8.81	8.15	16.96
4	28.8	33.8	7.06	4.99	12.06
5	30	37.2	11.43	4.77	16.21
Average	29.9	34.2	9.4	8.0	17.4

*Depth expressed as a percentage of total specimen thickness found between muscle and SFS.

mass index and lymphatic distribution or the relative location of the superficial fascial system. Lymphatic prevalence did not increase in the specimens taken near the superficial inferior epigastric vein.

DISCUSSION

Seroma formation remains a frequent complication in body contouring surgery.[10–21] The incidence of fluid collection after abdominoplasty varies among the reported series, with an overall average of approximately 10 percent. The pathogenesis of seroma has been attributed to many potential mechanisms, including vascular and lymphatic channel disruption, dead space formation, and the presence of shearing forces between tissue planes. In addition, potential risk factors correlated with seroma formation have included bleeding, smoking, obesity, and mass of excised abdominal skin.[22–25] Although benign in nature, seromas frequently cause discomfort and anxiety in patients, generating frequent office visits, procedures for treatment, and increased cost. Prevention—defined as any possible measure that reduces the chances of seroma formation—is the ideal best treatment.[5,23,26–29]

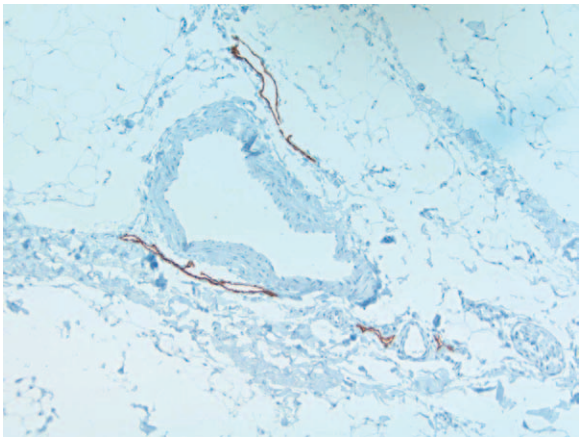

Fig. 3. Lymphatic vessels in the superficial fascia primarily accompany adjacent veins and arteries (D2-40).

Although the physiology underlying seroma formation remains ill-defined, several therapeutic interventions have been reported to significantly decrease seroma rates. Recent publications have advocated benefits of the lipoabdominoplasty technique, including a lower rate of wound complications and seroma rates of 0 to 3 percent.[1,3–7,27,30–32] Generally cited principles of this technique include limited supraumbilical undermining with selective liposuction of the lower abdomen to spare deeper structures.[1,7,32] Graf et al. demonstrated that limited epigastric undermining preserves vascular perforators from the deep epigastric system.[3] Fang et al. found decreased seroma formation with the elevation of a more superficial skin flap.[33] Presumably, decreased dead space and preservation of vascular and lymphatic structures contribute to lower seroma rates. Another approach has been the addition of quilting sutures between the abdominal flap and underlying fascia as advocated by Pollock and Pollock[29,34] and Le Louarn and Pascal.[27] In a 597-patient series, Pollock and Pollock reported only a single seroma after the placement of 10 to 18 progressive tension sutures.[29] In contrast to lipoabdominoplasty series, the authors attributed the decrease in seromas primarily to flap immobilization and decreased shear between tissue planes.

Our study sought to identify abdominal lymphatics by immunohistopathology. We focused on anatomical landmarks that have been advocated to be relevant to abdominoplasty (i.e., skin, subcutaneous tissue, superficial fascial system, and areolar tissue). We were able to reliably identify the lymphatic architecture of both the abdominal dermis and fascial layers. We examined specimens that were near the superficial epigastric vessels to look for any parallel collector system travelling with the superficial vasculature. These regions did not have an increased number of lymphatics, suggesting that although lymphatics often accompany small vessels within the fascial layers,

they appear to drain to central, deeper lymphatic systems rather than converging back to collectors near large vascular structures such as the superficial epigastrics.

As expected, the superficial and deep fat pockets had the smallest volume of lymphatic channels (Fig. 4). Lymphatics were most prevalent in the superficial and deep dermis. Although only one-fifth of abdominal lymphatics were found in the fascial layers, they may be significant. Because of technical limitations, the diameter of the lymphatic vessels within each layer cannot be calculated precisely, but based on the study by Felmerer et al., these plexuses within the fascial layers may represent larger collector systems.[35] From a clinical perspective, we define these two fascial layers as the deep abdominal lymphatic system, as both run in the deepest third of the abdominal wall, a finding that was consistent regardless of the body mass index or body habitus of the patients in this study.

The lymphatic network is a complex system composed of variably sized vascular channels lined by specialized endothelial cells, which drain interstitial fluid and lymph from peripheral tissues and return them to the venous system for recirculation.[36,37] Our knowledge of the lymphatic system is limited, especially in the field of gross anatomy. Pan et al. and Suami et al. have contributed important data regarding the lymphatics of the upper torso, head and neck, and upper limb using radiographic lymph injection techniques.[38–43] Because of the technical challenges associated with this specific region, there are relatively few data analyzing the lymphatic architecture of the abdominal wall.

Felmerer et al. used intradermal injections of Turnbull blue in fresh abdominal samples and demonstrated only superficial lymphatic channels that were located adjacent to the dermis and travelling parallel to the surface. Because of technical limitations, they were not able to demonstrate any lymphatics deeper than the dermis in the abdominal flap.[35] Postmortem visualization of lymphatic vasculature of the abdomen is also very difficult for the same reason (i.e., the significantly smaller diameter of the collector vessels in the abdominal region as opposed to the extremities). The development of an immunohistochemical stain for lymphatic vessels therefore represents an exciting step forward in the study of lymphatic architecture.

Although this anatomical study confirms the presence of deep lymphatic vessels, several additional questions still need to be answered. First, because only approximately 17 percent of lymphatic vessels are in the deep tissue, is this density of channels sufficient to clear dependent fluid from the dead space? Second, if the sub–Scarpa tissues are liposuctioned, will lymphatic channels retain function? Lastly, if dissection above the Scarpa fascia does impact seroma rates, is the benefit attributable to preservation

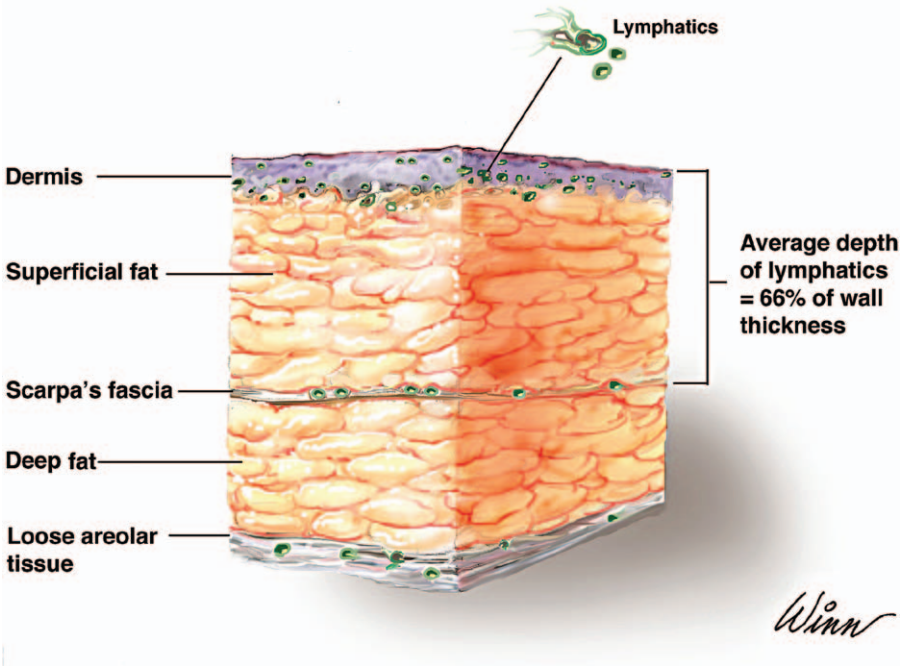

Fig. 4. Schematic diagram of the relationship demonstrates the lymphatic system across the different layers of the abdominal wall.

of lymphatics or to changing the interface of the tissues from subcutaneous fat against fascia to subcutaneous fat against a fat layer? Future studies should address these questions of significant clinical relevance.

CONCLUSIONS

In this study to define the superficial and deep lymphatics of the anterior abdominal wall, we found that the majority of lymphatic vessels were seen in the dermis, with approximately one-fifth appearing near fascial layers. The Scarpa fascia and its lymphatics are generally found at approximately two-thirds of the total depth of the abdominal wall specimen. The findings of this study may provide a rationale for clinical reports of lower seroma rates with preservation of the Scarpa fascia during abdominoplasty. Further studies are necessary to assess how effective lipoabdominoplasty methods are at functionally preserving these structures and correlate these anatomical findings with patient outcomes.

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REFERENCES

1. Avelar JM. Abdominoplasty combined with lipoplasty without panniculus undermining: Abdominolipoplasty—A safe technique. *Clin Plast Surg.* 2006;33:79–90, vii.
2. Espinosa-de-los-Monteros A, de la Torre JI, Rosenberg LZ, et al. Abdominoplasty with total abdominal liposuction for patients with massive weight loss. *Aesthetic Plast Surg.* 2006;30:42–46.
3. Graf R, de Araujo LR, Rippel R, Neto LG, Pace DT, Cruz GA. Lipoabdominoplasty: Liposuction with reduced undermining and traditional abdominal skin flap resection. *Aesthetic Plast Surg.* 2006;30:1–8.
4. Heller JB, Teng E, Knoll BI, et al. Outcome analysis of combined lipoabdominoplasty versus conventional abdominoplasty. *Plast Reconstr Surg.* 2008;121:1821–1829.
5. Le Louarn C, Pascal JF. High superior tension abdominoplasty. *Aesthetic Plast Surg.* 2000;24:375–381.
6. Matos WN Jr, Ribeiro RC, Marujo RA, da Rocha RP, da Silva Ribiero SM, Carrillo Jiminez FV. Classification for indications of lipoabdominoplasty and its variations. *Aesthet Surg J.* 2006;26:417–431.
7. Saldanha OR, De Souza Pinto EB, Mattos WN Jr, et al. Lipoabdominoplasty with selective and safe undermining. *Aesthetic Plast Surg.* 2003;27:322–327.
8. Uebel CO. Lipoabdominoplasty: Revisiting the superior pull-down abdominal flap and new approaches. *Aesthetic Plast Surg.* 2009;33:366–376.
9. Kahn HJ, Bailey D, Marks A. Monoclonal antibody D2-40, a new marker of lymphatic endothelium, reacts with Kaposi's sarcoma and a subset of angiosarcomas. *Mod Pathol.* 2002;15:434–440.
10. Albino FP, Koltz PF, Gusenoff JA. A comparative analysis and systematic review of the wound-healing milieu: Implications for body contouring after massive weight loss. *Plast Reconstr Surg.* 2009;124:1675–1682.
11. Au K, Hazard SW III, Dyer AM, et al. Correlation of complications of body contouring surgery with increasing body mass index. *Aesthet Surg J.* 2008;28:425–429.
12. Capella JF. Body lift. *Clin Plast Surg.* 2008;35:27–51; discussion 93.
13. Friedman T, O'Brien Coon D, Michaels J, et al. Fleur-de-lis abdominoplasty: A safe alternative to traditional abdominoplasty for the massive weight loss patient. *Plast Reconstr Surg.* 2010;125:1525–1535.
14. Hurwitz DJ, Agha-Mohammadi S, Ota K, Unadkat J. A clinical review of total body lift surgery. *Aesthet Surg J.* 2008;28:294–303; discussion 304–305.
15. Matarasso A, Aly A, Hurwitz DJ, Lockwood TE. Body contouring after massive weight loss. *Aesthet Surg J.* 2004;24:452–463.
16. Michaels J V, Coon D, Rubin JP. Post-bariatric surgery body contouring: A learning curve. *Plast Reconstr Surg.* 2011;127:69e–70e.
17. Michaels J V, Coon D, Rubin JP. Complications in postbariatric body contouring: Strategies for assessment and prevention. *Plast Reconstr Surg.* 2011;127:1352–1357.
18. Michaels J V, Coon D, Rubin JP. Complications in postbariatric body contouring: Postoperative management and treatment. *Plast Reconstr Surg.* 2011;127:1693–1700.
19. Momeni A, Heier M, Bannasch H, et al. Complications in abdominoplasty: A risk factor analysis. *J Plast Reconstr Aesthet Surg.* 2009;62:1250–1254.
20. van der Beek ES, van der Molen AM, van Ramshorst B. Complications after body contouring surgery in post-bariatric patients: The importance of a stable weight close to normal. *Obes Facts* 2011;4:61–66.
21. Zuelzer HB, Ratliff CR, Drake DB. Complications of abdominal contouring surgery in obese patients: Current status. *Ann Plast Surg.* 2010;64:598–604.
22. Chaouat M, Levan P, Lalanne B, Buisson T, Nicolau P, Mimoun M. Abdominal dermolipectomies: Early postoperative complications and long-term unfavorable results. *Plast Reconstr Surg.* 2000;106:1614–1618; discussion 1619–1623.
23. Kulber DA, Bacilious N, Peters ED, Gayle LB, Hoffman L. The use of fibrin sealant in the prevention of seromas. *Plast Reconstr Surg.* 1997;99:842–849; discussion 850–851.
24. Shermak MA, Rotellini-Coltvet LA, Chang D. Seroma development following body contouring surgery for massive weight loss: Patient risk factors and treatment strategies. *Plast Reconstr Surg.* 2008;122:280–288.
25. Zimman OA, Butto CD, Ahualli PE. Frequency of seroma in abdominal lipectomies. *Plast Reconstr Surg.* 2001;108:1449–1451.
26. Baroudi R, Ferreira CA. Seroma: How to avoid it and how to treat it. *Aesthet Surg J.* 1998;18:439–441.
27. Le Louarn C, Pascal JF. The high-superior-tension technique: Evolution of lipoabdominoplasty. *Aesthetic Plast Surg.* 2010;34:773–781.
28. Pollock H, Pollock T. Progressive tension sutures: A technique to reduce local complications in abdominoplasty. *Plast Reconstr Surg.* 2000;105:2583–2586; discussion 2587–2588.
29. Pollock TA, Pollock H. Progressive tension sutures in abdominoplasty: A review of 597 consecutive cases. *Aesthet Surg J.* 2012;32:729–742.
30. Huger WE Jr. The anatomic rationale for abdominal lipectomy. *Am Surg.* 1979;45:612–617.

31. Nahai FR. Anatomic considerations in abdominoplasty. *Clin Plast Surg.* 2010;37:407–414.
32. Saldanha OR, Federico R, Daher PF, et al. Lipoabdominoplasty. *Plast Reconstr Surg.* 2009;124:934–942.
33. Fang RC, Lin SJ, Mustoe TA. Abdominoplasty flap elevation in a more superficial plane: Decreasing the need for drains. *Plast Reconstr Surg.* 2010;125:677–682.
34. Pollock TA, Pollock H. No-drain abdominoplasty with progressive tension sutures. *Clin Plast Surg.* 2010;37:515–524.
35. Felmerer G, Muehlberger T, Berens von Rautenfeld D, Vogt PM. The lymphatic system of the deep inferior epigastric artery perforator flap: An anatomical study. *Br J Plast Surg.* 2002;55:335–339.
36. Oliver G, Srinivasan RS. Lymphatic vasculature development: Current concepts. *Ann N Y Acad Sci.* 2008;1131:75–81.
37. Reis RM, Reis-Filho JS, Longatto Filho A, Tomarev S,Silva P, Lopes JM. Differential Prox-1 and CD 31 expression in mucousae, cutaneous and soft tissue vascular lesions and tumors. *Pathol Res Pract.* 2005;201:771–776.
38. Pan WR, Rozen WM, Stretch J, Thierry B,Ashton MW, Corlett RJ. Advanced imaging technologies for mapping cadaveric lymphatic anatomy: Magnetic resonance and computed tomography lymphangiography. *Lymphology* 2008;41:126–130.
39. Pan WR, Suami H, Taylor GI. Lymphatic drainage of the superficial tissues of the head and neck: Anatomical study and clinical implications. *Plast Reconstr Surg.* 2008;121:1614–1624; discussion 1625–1626.
40. Suami H, O'Neill JK, Pan WR, Taylor GI. Superficial lymphatic system of the upper torso: Preliminary radiographic results in human cadavers. *Plast Reconstr Surg.* 2008;121:1231–1239.
41. Suami H, O'Neill JK, Pan WR, Taylor GI. Perforating lymph vessels in the canine torso: Direct lymph pathway from skin to the deep lymphatics. *Plast Reconstr Surg.* 2008;121:31–36.
42. Suami H, Taylor GI, O'Neill J, Pan WR. Refinements of the radiographic cadaver injection technique for investigating minute lymphatic vessels. *Plast Reconstr Surg.* 2007;120:61–67.
43. Suami H, Taylor GI, Pan WR. The lymphatic territories of the upper limb: Anatomical study and clinical implications. *Plast Reconstr Surg.* 2007;119:1813–1822.

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