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Where does subcutaneous lymph from the chest wall flow into after mastectomy?

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Summary *Background:* Changes of the lymph flow from the chest wall after mastectomy and sentinel lymph node biopsy (SLNB) or axillary lymph node dissection (Ax) has yet to be understood. This study aimed to investigate the effect of axillary surgery on lymphatic flow from the chest wall in patients who have undergone mastectomy, including those have undergone breast reconstruction and vascularized lymph node transfer (VLNT).
Methods: Following mastectomy in 100 breasts, the directions of lymph flow from the chest wall was compared between the SLNB omission, SLNB, Ax, and Ax followed by VLNT groups using indocyanine green (ICG) lymphography in cross-sectional study. Lymph flow on the deep epigastric artery perforator (DIEP) flap was also investigated.
Results: Lymph flow directing to the ipsilateral axilla was observed more frequently after SLNB than Ax (48% vs. 12.5%; $p = 0.005$); however, no significant difference was observed in the frequency of contralateral axillary route adoption between them (8% vs. 15%; $p = 0.65$). In the VLNT group, lymph flow to the ipsilateral axilla was not observed at a significantly higher frequency than in the Ax group (12.5% vs. 12.5%, $p = 1.00$). On the transferred DIEP flap, the lymph flowed anterograde or retrograde parallel to the anatomic course of the lymphatic vessels.

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Conclusion: To visualize the direction of lymph flow of the chest following mastectomy, ICG lymphography may be useful to discern the direction in which malignant neoplasms, including lymphoma, are transported and to plan for lymph flow restoration.

Introduction

Surgical invasion for axillary lymph nodes (LNs) in breast cancer surgery may alter the direction of lymph flow to the LN basins across the chest wall. According to detailed anatomical studies conducted by Suami et al. and clinical studies on sentinel lymph node biopsy (SLNB) conducted by breast surgeons, the pathway of the subcutaneous collecting lymphatic vessels above the deep fascia in the anterior chest wall almost always flows into a few LNs in the axilla as a superficial lymphatic system[1-6]. Lymph flow deeper than the deep fascia, including the internal mammary lymphatic system, communicates with the mammary gland tissue but has little contact with the superficial pathway[1-6]. Following the surgical invasion, the lymph flow in the superficial system may either flow toward the axilla again, change its course to another direction, or become stagnant.

In the literature, studies on lymph flow to the axilla following surgical treatment have been described from the oncologic perspective.[7-13] Because the purpose of these studies has been second SLNB for ipsilateral breast tumor recurrence, all subjects investigated were those with cancer recurrence in the ipsilateral chest.[7-13] In addition, most subjects were patients who had previously undergone breast-conserving surgery for the same reason.

Postoperative breast cancer patients visiting the offices of plastic surgeons usually have no recurrence of breast cancer and the purposes of the visit are breast reconstruction following mastectomy and/or breast cancer-related lymphedema (BCRL) on the upper extremity.[14] Although surgical interventions conducted by plastic surgeons to treat these diseases may affect the direction of the lymph flow in the chest, to our knowledge, these effects have not been investigated.

Recently, breast implant-associated anaplastic large-cell lymphoma (BIA-ALCL) has become a very important issue in the field of breast reconstruction. In the proposed TNM classification of BIA-ALCL, it is important to detect the range of LN metastasis capable of exceeding the regional LNs.[15]

BCRL is a complication that reduces the quality of life of patients after breast cancer treatment, including not only after lymphadenectomy, but also after only SLNB at a certain rate.[16-19] Vascularized LN transfer (VLNT) has been reported to be useful in the management of BCRL[20-22]. The afferent and efferent lymphatics play an important role in the lymphatic drainage mechanism in VLNT, and as Chen et al. showed, the anastomosed vein is an important outflow tract[23,24]. Experimental and clinical studies using indocyanine green (ICG) lymphography have shown that the anatomical position of the transferred tissue and patency of the anastomosed vessels play important roles in VLNT[23-27]. However, no study has investigated whether lymph flow from the chest wall to transferred LN in the axilla is observed. In the present study, we investigated differences in subcutaneous lymph flow of the chest wall after mastectomy among patients who underwent different surgical procedures for the axilla, including those who have undergone breast reconstruction or/and VLNT following mastectomy.

This study aimed to investigate the effect of axillary surgery on subcutaneous lymph flow of the chest wall in patients who have undergone mastectomy, including those who have undergone breast reconstruction or/and VLNT. Obtaining knowledge of changes in the lymphatic drainage pathway of the chest wall following mastectomy and axillary surgeries would be of great help in advancing our understanding of mechanism of repair after lymph flow injury.

Patients and methods

This cross-sectional study was carried out at the Chiba University Hospital in Chiba, Japan with approval from the relevant institutional review board and permission from the ethics committee (No. 3000). The study was in accordance with the Declaration of Helsinki. Written informed consent to participate in this study was obtained from all selected study participants prior to their inclusion.

Inclusion criteria for this study were as follows: patients who had undergone mastectomy and who had BCRL, suspected BCRL, or subclinical BCRL, based on the subjective symptom of the patients. Patients who had undergone breast reconstruction and/or lymphatic microsurgery for BCRL following mastectomy also met the inclusion criteria. Patients with a duration of >6 months between the primary surgery and ICG angiography were also eligible. Patients with breast lymphedema or suspected breast lymphedema were excluded. In the patients who presented following bilateral breast cancer, the examination was performed bilaterally in the chest but, even in the patients diagnosed with unilateral breast cancer, the lymph flow of the chest in the contralateral side was also examined if the patient wished to be examined because there is a risk of impairment in lymphatic function in the contralateral side among those with unilateral BCRL following unilateral breast cancer.[28]

At this point, 0.2 mL of 2.5 mg/mL ICG solution (Diagnogreen®, 25 mg; Daiichi Sankyo Co., Ltd., Tokyo, Japan) was injected subcutaneously to the second interdigit and fourth interdigit of the upper extremity and center of the mastectomy area[29]. The center of the mastectomy area was defined as the upper lateral quadrant of the nipple in the patient who had undergone nipple-sparing mastectomy, 1 cm cephalad lateral to the median surgical margin in patients who had undergone mastectomy resecting nipple-areola complex, and the point where the upper lateral quadrant of the nipple was supposed to be in patients who had undergone breast reconstruction. At 1 h after injection, a near-infrared monitoring camera (Pde-neo®; Hamamatsu Photonics K.K., Hamamatsu City, Japan) was used to monitor and record the thoracic and axilla imaging findings. When no lymphatic flow from the injected site

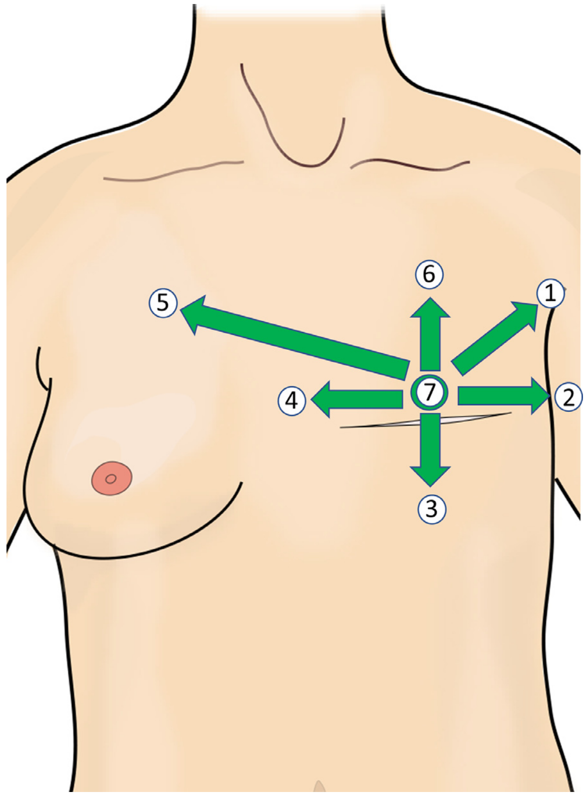

Figure 1 Lymph flow from the injected point was categorized into the following six directions and no flow: 1, ipsilateral axilla; 2, lateral thorax; 3, caudal region; 4, parasternal region; 5, contralateral axilla; or 6, clavicular directions.

was observed, manual drainage at the injected site was attempted to facilitate ICG entry into lymphatic vessels. As the images of the right and left chest walls might intersect, when bilateral examinations were performed, the contralateral examination was performed after one examination was completed.

The directions of linear lymphatic drainage channels from the upper lateral region of the breast on ICG lymphography were classified into 1, ipsilateral axilla; 2, lateral thorax; 3, caudal region; 4, parasternal region; 5, contralateral axilla; or 6, clavicular region. When no linear pattern was observed even after manual drainage to the injected point, the result was recorded as 7, no linear flow (Figure 1). When multiple directions were observed, all directions to which the linear pattern was directed were recorded. As patients with breast lymphedema were excluded, extensive dermal back flow (DBF) was assumed to not spread throughout the chest by injecting it into the center of the breast. The lymph flow from the center of the breast was completely distinguishable from that of the lymphatic inflow of the ipsilateral hand by confirming the direction of the linear pattern continuously from the injection site and enhance the imaging effect through the soft manual drainage.

All 100 breasts were categorized into four groups based on previous surgical procedures performed in the axilla, and the direction of lymph flow was compared between the groups.

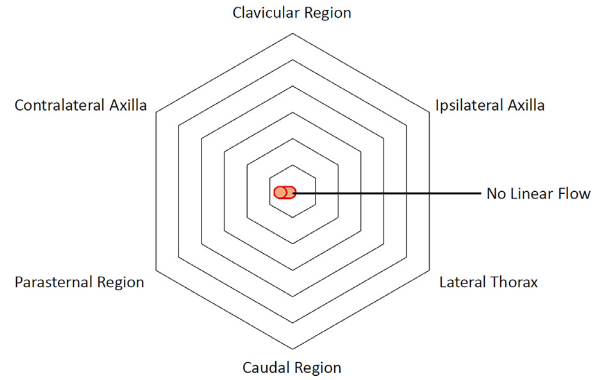

Figure 2 The directions of lymph outflow following mastectomy were drawn in a breast chart mimicking the radar chart. In right breast cancer, the actual position was reversed, and all cases were plotted with ipsilateral axilla at the upper right of the chart and contralateral axilla at the upper left of the chart.

1) When SLNB was omitted at the time of mastectomy, the chest was categorized into the SLNB omission group.
2) When SLNB had been performed, the chest was categorized into the SLNB group.
3) When axillary LN dissection (Ax) had been performed, the chest was categorized into the Ax group.
4) When Ax had been performed followed by VLNT to the axilla later for postoperative chronic BCRL, the chest was categorized into the Ax followed by VLNT group. The recipient site of VLNT was axilla in all the patients included in this study.

To visualize differences in the direction of lymph outflow in each group, a breast chart mimicking the radar chart was created (Figure 2). If more than one drainage route was observed, all directions seen were recorded and the percentage of the study population in which drainage in that direction was observed was shown. Therefore, the sum of all directions in the breast chart exceeds 100%.

During the course of this study, the lymph flow in the tissues used for reconstruction could also be observed when the skin paddle of the flap was located at the center of the breast. The deep epigastric artery perforator (DIEP) flap is the most frequently used reconstruction material at our institution. The anatomic lymph flow direction in the subcutaneous tissue of the skin of the lower abdomen where the DIEP flap was designed is from the umbilicus to the caudal side.[30] During breast reconstruction, flaps were placed in various orientations to match the shape of the breast in the patients included in this study. The observed direction of the linear pattern after transference was classified as anterograde, retrograde, or perpendicular to the anatomical lymph flow direction (Figure 3).

The primary endpoint of this study was to determine whether the frequency of subcutaneous lymph flow exists from the chest wall to the ipsilateral axilla following mastectomy during the period between SLNB and Ax. The study also investigated whether the frequency of lymph flow from the chest wall to the ipsilateral axilla increased after VLNT. The secondary endpoint was to determine whether the direction of the lymph flow in the transferred DIEP flap on the

Table 1 Basic characteristics of the patients in each group.

	SLNB Omission	SLNB	Ax	Ax followed by VLNT
Total number	3	25	40	32
Age (years)	54.3 ± 2.9	52.2 ± 8.6	57.2 ± 15.8	68.7 ± 9.4
BMI	21.3 ± 1.3	22.4 ± 3.0	23.4 ± 3.5	23.7 ± 2.6
Radiation	0	1	29	29
BCRL	0	1	27	32

SLNB, sentinel lymph node biopsy; Ax, axillary lymph node dissection, VLNT; vascularized lymph node transfer; BMI, body mass index; BCRL, breast cancer-related lymphedema

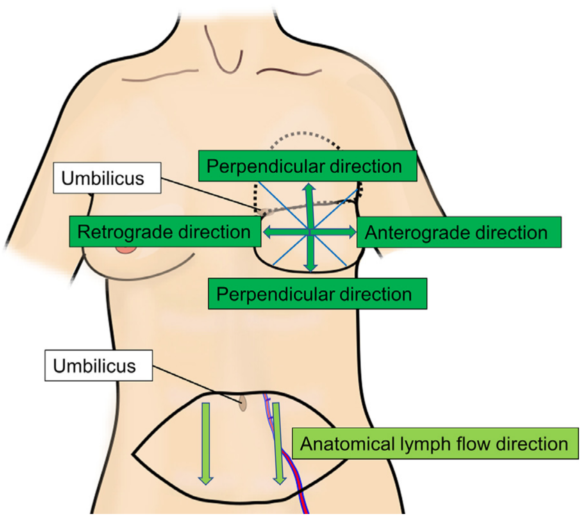

Figure 3 The anatomic lymph flow direction in the DIEP flap was assumed to be from the umbilicus to the caudal side. The observed direction of the linear pattern in the transferred DIEP flap was classified as anterograde, retrograde, or perpendicular to the anatomical lymph flow direction.

chest wall was changed from the preoperative anatomical direction of the lymph flow.

Statistical analysis

Statistical analyses among the groups were performed using the JMP statistical software (version 13; SAS Institute Inc., Cary, NC, USA). The chi-squared test and Fisher's exact test were used to compare the ratio of the chest the lymphatic flow between the SLNB and Ax groups and the Ax and Ax followed by VLNT groups, respectively. The Kappa coefficient was used to ascertain the consistency between the direction of anatomical collecting lymphatic channels in the DIEP flap and the direction of ICG outflow after flap transference. A p-value of less than 0.05 was considered to be statistically significant. The data are presented as means ± standard deviations.

Results

A total of 100 sides of the chest wall following the mastectomies of 89 patients (78 unilateral and 11 bilateral mastectomies) were examined and analyzed. Eleven unoperated contralateral normal breasts in 11 patients who had undergone unilateral mastectomy were also examined using ICG. The average duration between breast oncologic surgery and examination of the 100 breasts was 79.8 ± 95.6 months. Three (25, 40, and 32) breasts chest walls were categorized into the SLNB omission, SLNB, Ax, and Ax followed by VLNT groups, respectively. The basic characteristics of each group are listed in Table 1.

For the upper limbs, although all patients subjectively experienced upper extremity edema, no overt BCRL with a circumference change was observed upon examining 47 arms (Normal or International Society of Lymphology [ISL] clinical stage 0). Thirty-seven arms had ISL clinical stage 1 BCRL and 16 arms had ISL clinical stage 2 BCRL. In ICG lymphography of the upper extremity, DBF pattern, which indicates objective upper extremity lymphedema, was observed in 0, 2, 27, and 32 limbs in the SLNB omission, SLNB, Ax, and Ax followed by VLNT groups, respectively. The findings of ICG lymphography were not normalized in any patient following VLNT for BCRL in this study.

In all of the 11 unoperated contralateral breasts, the direction of ICG drainage from the breast was toward the ipsilateral axilla.

The directions of lymph drainage of 100 breasts are listed in Table 2 and breast charts are displayed in Figure 4. Typical patterns of ICG lymphography are shown in **Supplemental digital content 1**.

In the SLNB omission group, the direction of ICG drainage in the chest was toward the ipsilateral axilla in all breasts. Since the number of chests in the SLNB omission group was very small, a statistical analysis was performed to compare the differences in the surgical procedures for the axilla between SLNB and Ax groups. When the direction of the lymph flow was categorized as toward the ipsilateral axilla versus all other directions, lymphatic flow from the chest wall to the axilla was observed significantly more frequently in the SLNB group than in the Ax group (48% vs. 12.5%; $p = 0.005$). Furthermore, lymph flow directing to the contralateral axilla was observed at a frequency of 8% in the SLNB group and 15% in the Ax group, with no significant difference between the two groups ($p = 0.65$).

To elucidate the effects of VLNT on lymph flow from the chest wall, the difference between the Ax group and Ax followed by VLNT group was analyzed. Between the Ax group and Ax followed by VLNT group, there was no significant difference in the frequency of ipsilateral axillary flow (12.5 % vs. 12.5 %; $p = 1.00$). There was also no significant difference in the frequency of contralateral axillary flow between these groups (15.0% vs. 6.3%; $p = 0.20$).

Among 100 breasts, 52 breasts had undergone breast reconstruction using DIEP flap. The injection point was located

Table 2 Direction of lymph flow from the chest wall in each group.

	SLNB Omission	SLNB	Ax	Ax followed by VLNT
Ipsilateral Axilla	3	12	5	4
Lateral Thorax	0	3	2	1
Caudal Region	0	0	3	1
Parasternal Region	0	12	28	19
Contralateral Axilla	0	2	6	2
Clavicular Region	0	4	2	2
No Linear Flow	0	0	4	8

SLNB, sentinel lymph node biopsy; Ax, axillary lymph node dissection, VLNT; vascularized lymph node transfer

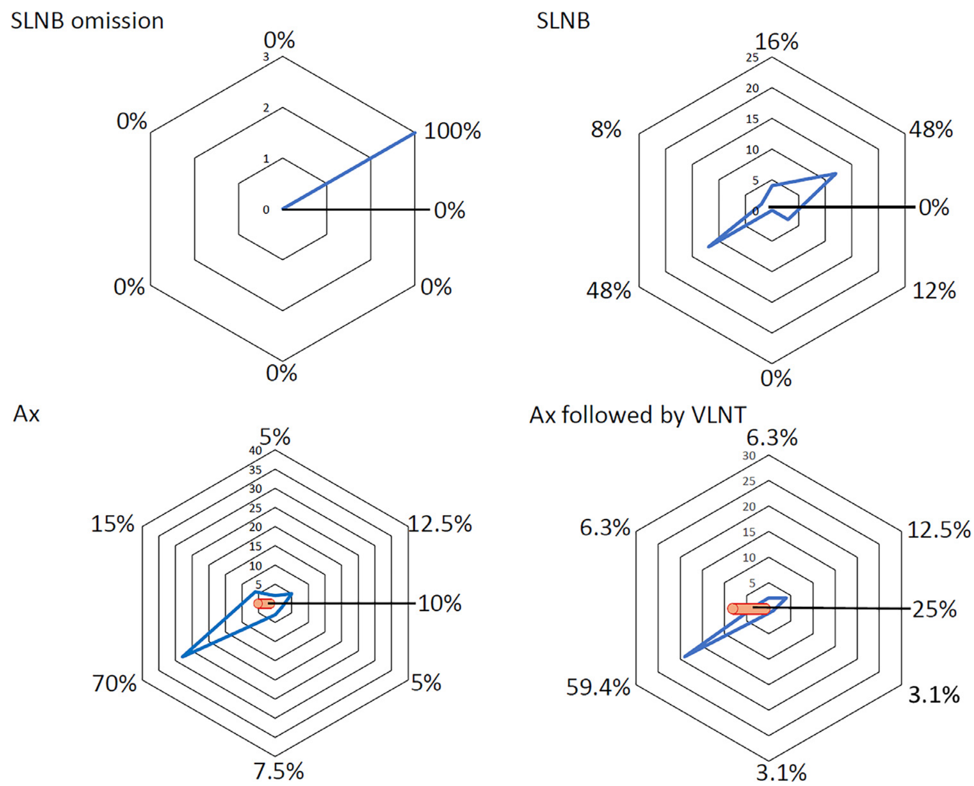

Figure 4 Breast charts of each group following mastectomy are shown. Note that the percentage on each chart is a percentage of the number of subjects in each group. When a linear pattern was observed in multiple directions, all directions were recorded, so the total percentage of all components in the chart could exceed 100. SLNB omission; sentinel lymph node was omitted and no axillary surgery was performed. SLNB; sentinel lymph node biopsy, Ax; axillary lymph node dissection, Ax followed by VLNT; Ax followed by vascularized lymph node transfer later for postoperative chronic breast cancer-related lymphedema.

on the skin paddle in 27 of them, and it was possible to observe the lymph flow under the DIEP flap in these cases. In five of them, a linear pattern was not observed on the skin paddle, while, in the other 22 breasts, a linear pattern was observed. During the design of the DIEP flap, assuming that the umbilico-caudal direction had been the original lymph flow before flap elevation, the flow direction observed by ICG lymphography in the chest wall after flap transfer was anterograde, retrograde, and both anterograde and retrograde in 7, 13, and two of the 22 flaps, respectively. No linear pattern perpendicular to the direction of anatomic lymphatic pathway of the recipients was observed. In total, anterograde flow was observed in nine of 22 flaps. The Kappa coefficient was 0.14, and there was only a slight agreement between the direction of anatomical collecting lymphatics in the DIEP flap and the direction of ICG outflow after transference.

Discussion

In this study, the direction of lymphatic drainage on the chest wall after mastectomy was analyzed for the first time. In the untreated breast and SLNB omission group after mastectomy, only ipsilateral axillary inflow was observed in all the chests. Although inconclusive due to the small number of samples, the results were consistent with those of existing studies, which shows that lymphatic pathways from the subcutaneous tissue of the anterior chest is connected to one or few axillary SLNs in most cases[1-6]. Once lymph flow to the axilla was blocked, lymph flow to the other direction was observed more frequently after Ax than after SLNB, but direct contralateral axillary lymph flow was often observed in both cases. Future studies comparing treated with untreated breasts might be more useful to detect intraindividual variations and would provide more solid evidence for the results of this study.

In addition to cancer recurrence and metastasis, BIA-ALCL is at present of great concern to plastic surgeons and breast surgeons. The results of this study suggest that lymph flow is frequently directed away from the ipsilateral axilla, particularly in patients after Ax. Neoplasms arising in the chest wall after mastectomy may travel in a different pathway from the anatomical lymphatic pathway. Since the determination of whether contralateral axillary metastases are distant metastases or regional LN metastasis may affect severity classification, further studies revealing chest wall lymph flow after mastectomy are warranted.[31]

We herein investigated the possibility of lymph flow from the chest wall to the transplanted LNs as well as lymph flow from the upper limbs to the transplanted LNs when the axilla was selected as a recipient site for VLNT. In this study, the frequency of lymph flow from the chest wall to the ipsilateral axilla did not increase after VLNT. Recently, the importance of reverse mapping has been reported as a means to help avoid donor site morbidity following VLNT.[32] Along these lines, intraoperative reverse mapping was performed in all patients in this study.[22] In all cases, the upper lateral superficial circumflex iliac artery (SCIA)-fed LNs were transplanted, and the soft tissue in the SCIA-fed area was located across the axilla in the upper arm.[33] Yamamoto et al. reported that the axial nature of lymph flow in the transplanted tissue is important for the regeneration of lymph flow between the recipient and the transplanted tissue.[34] During VLNT, the transplanted tissue was positioned to facilitate inflow from the upper arm, so it is speculated in this context that the lymph flow from the chest wall did not frequently change its direction to the axilla. The results of this study suggest that the risk of VLNT inducing the lymph flow from neoplasms in the chest wall is reduced by placing the flap in consideration of the direction of lymph flow. One of the limitations of this study was that lymphatic drainage from the upper extremities to the axilla was not included in the endpoint. In addition, the possibility cannot be ruled out that the lymphatic inflow to the axilla was deeper than the depth observed by ICG lymphography. Further investigation is needed in the observation of axillary LNs after VLNT.

As the mechanism of lymph flow changes after damage of the lymph flow or its reconstruction, the alternate pathway is assumed to be utilized and/or that lymphangiogenesis occurred. As a critical limitation, this was a cross-sectional study comprising various patients. Postoperative serial assessment in future studies would potentially better elucidate these possibilities.

In additional analysis of the present study focusing on the cases following DIEP flap, the direction of anatomic lymph flow before flap elevation was not maintained in the transferred flap in the anterograde direction. However, in all cases wherein a linear pattern was observed, lymph flow in the anterograde and/or 180° retrograde directions were observed and not so in the perpendicular direction. The axiality of lymph flow is maintained in all cases after transplantation, allowing for retrograde flow. These results suggest that retrograde placement may also be acceptable in the planning restoration of lymph flow using free-flap transfer.[34]

One of the limitations of this study was that the routes into the deep lymphatic system could not be confirmed due to the limited ability of ICG lymphography, especially through perforating lymphatics along the branch from the internal mammary artery. Although the development of lymphatic flow directly into the deep system without passing through the superficial lymphatic system from the subcutaneous injection at the region of the perforating branch frequently occurs, further research using other modalities such as SPECT-CT may shed light on this topic.[35] Another limitation of the study was that various surgical methods other than axillary manipulation were included, such as the amount of skin resection for mastectomy, breast reconstruction methods, and position of transferred tissue. Prospective studies that unify the surgical methods may prove the findings suggested in this study.

Conclusion

Subcutaneous lymph flow from the chest wall to the ipsilateral axilla following mastectomy was observed more frequently after SLNB than after Ax; however, the resumption of lymph flow in other directions, including the contralateral axilla, was common after either procedure. In contrast, following VLNT, lymph flow from the chest to the transferred LNs was not observed very often. Understanding the direction of lymph flow from the chest wall following mastectomy may be useful to discern the direction in which malignant neoplasms, including lymphoma, are transported and to plan for lymphatic flow restoration.

Ethical consent

This study was conducted in accordance with the World Medical Association Declaration of Helsinki in Chiba University Hospital (Chiba, Japan) with the approval of the institutional review board and permission from the ethics committee (No. 3000). Written permission for the publication of photographs was obtained from all patients.

Financial disclosure statement

No financial contribution was received during preparation of this manuscript.

Declaration of Competing Interest

None declared.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2021.03.112.

References

1. Suami H, Pan WR, Mann GB, Taylor GI. The lymphatic anatomy of the breast and its implications for sentinel lymph node biopsy: a human cadaver study. *Ann Surg Oncol* 2008;**15**:863-71.
2. Suami H. Lymphosome concept: anatomical study of the lymphatic system. *J Surg Oncol* 2017;**115**:13-17.
3. Pavlista D, Eliska O. Cutaneous and subcutaneous lymphatic drainage of the breast. *Lymphology* 2005;**38**:92-102.
4. Veronesi U, Paganelli G, Galimberti V, et al. Sentinel-node biopsy to avoid acillary dissection in breast cancer with clinically negative lymph-nodes. *Lancet* 1997;**349**:1864–7.
5. Borgstein PJ, Meijer S, Pijpers R. Intradermal blue dye to identify sentinel lymph nodes in breast cancer. *Lancet* 1997;**349**:1668–9.
6. Linehan DC, Hill AD, Akhurst T, et al. Intradermal radiocolloid and intraparenchymal blue dye injection optimize sentinel node identification in breast cancer patients. *Ann Surg Oncol* 1999;**6**:450–4.
7. Sávolt Á, Cserni G, Lázár G, et al. Sentinel lymph node biopsy following previous axillary surgery in recurrent breast cancer. *Eur J Surg Oncol* 2019;**45**:1835-8.
8. Sato A, Sakai T, Iwase T, et al. Altered lymphatic drainage patterns in re-operative sentinel lymph node biopsy for ipsilateral breast tumor recurrence. *Radiat Oncol* 2019;**14**:159.
9. Matsumoto A, Jinno H, Nakamura T, et al. Technical feasibility of sentinel lymph node biopsy in patients with ipsilateral breast tumor recurrence and previous axillary surgery. *Int J Surg* 2015;**22**:28–31.
10. Intra M, Viale G, Vila J, Grana CM, et al. Second axillary sentinel lymph node biopsy for breast tumor recurrence: experience of the european institute of oncology. *Ann Surg Oncol* 2015;**22**:2372–7.
11. Pasta V, Monteleone F, D'Orazi V, et al. Typical and atypical lymphatic flows in breast carcinoma. *Ann Ital Chir* 2015;**86**:311-16.
12. Tokmak H, Kaban K, Muslumanoglu M, et al. Management of sentinel node re-mapping in patients who have second or recurrent breast cancer and had previous axillary procedures. *World J Surg Oncol* 2014;**12**:205.
13. Maaskant-Braat AJ, Roumen RM, Voogd AC. Sentinel node and recurrent breast cancer (SNARB): results of a nationwide registration study. *Ann Surg Oncol* 2013;**20**:620-6.
14. Schaverien MV, Coroneos CJ. Surgical treatment of lymphedema. *Plast Reconstr Surg* 2019;**144**:738–58.
15. Clemens MW, Medeiros LJ, Butler CE, et al. Complete surgical excision is essential for the management of patients with breast implant-associated anaplastic large-cell lymphoma. *Journal of Clinical Oncology;* 2016;**34**:160-8.
16. Belmonte R, Messaggi-Sartor M, Ferrer M, et al. Prospective study of shoulder strength, shoulder range of motion, and lymphedema in breast cancer patients from pre-surgery to 5 years after ALND or SLNB. *Support Care Cancer* 2018.
17. Killelea BK, Long JB, Dang W, et al. Associations between sentinel lymph node biopsy and complications for patients with ductal carcinoma in situ. *Ann Surg Oncol* 2018;**25**:1521-9.
18. Bhatt NR, Boland MR, McGovern R, et al. Upper limb lymphedema in breast cancer patients in the era of Z0011, sentinel lymph node biopsy and breast conservation. *Ir J Med Sci* 2018;**187** 327-1.
19. Boughey JC, Suman VJ, Mittendorf EA, et al. Sentinel lymph node surgery after neoadjuvant chemotherapy in patients with node-positive breast cancer: the ACOSOGZ1071 (Alliance) clinical trial. *JAMA* 2013;**310**:1455-61.
20. Saaristo AM, Niemi TS, Viitanen TP, et al. Microvascular breast reconstruction and lymph node transfer for postmastectomy lymphedema patients. *Ann Surg* 2012;**255**:468-73.
21. Becker C, Pham DN, Assouad J, et al. Postmastectomy neuropathic pain: results of microsurgical lymph nodes transplantation. *Breast* 2008;**17**:472–6.
22. Akita S, Tokumoto H, Yamaji Y, et al. Contribution of simultaneous breast reconstruction by deep inferior epigastric artery perforator flap to the efficacy of vascularized lymph node transfer in patients with breast cancer-related lymphedema. *J Reconstr Microsurg* 2017;**3**:571–8.
23. Cheng MH, Huang JJ, Wu CW, et al. The mechanism of vascularized lymph node transfer for lymphedema: natural lymphaticovenous drainage. *Plast Reconstr Surg* 2014;**133** 192e-8e.
24. Ito R, Zelken J, Cheng MH, et al. Proposed pathway and mechanism of vascularized lymph node flaps. *Gynecol Oncol* 2016;**141**:182–8.
25. Yamamoto T, Yoshimatsu H, Yamamoto N. Complete lymph flow reconstruction: a free vascularized lymph node true perforator flap transfer with efferent lymphaticolymphatic anastomosis. *J Plast Reconstr Aesthet Surg* 2016;**69**:1227-33.
26. Akita S, Yamaji Y, Tokumoto H, et al. Improvement of the efficacy of vascularized lymph node transfer for lower-extremity lymphedema via a prefabricated lympho-venous shunt through lymphaticovenular anastomosis between the efferent lymphatic vessel and small vein in the elevated vascularized lymph node. *Microsurgery* 2018;**38**:270–7.
27. Yoshimatsu H, Visconti G, Karakawa R, et al. Lymphatic system transfer for lymphedema treatment: transferring the lymph nodes with their lymphatic vessels. *Plast Reconstr Surg Glob Open* 2020;**8**:e2721.
28. Adams KE, Rasmussen JC, Darne C, et al. Direct evidence of lymphatic function improvement after advanced pneumatic compression device treatment of lymphedema. *Biomed Opt Express* 2010;**1**:114–25.
29. Akita S, Nakamura R, Yamamoto N, et al. Early detection of lymphatic disorder and treatment for lymphedema following breast cancer. *Plast Reconstr Surg* 2016;**138** 192e–202e.
30. Tourani SS, Taylor GI, Ashton MW. Scarpa fascia preservation in abdominoplasty: does it preserve the lymphatics? *Plast Reconstr Surg* 2015;**136**:258–62.
31. Clemens MW, Medeiros LJ, Butler CE, et al. Complete surgical excision is essential for the management of patients with breast implant-associated anaplastic large-cell lymphoma. *Journal of Clinical Oncology* 2016;**34**:160–8.
32. Dayan JH, Dayan E, Smith ML. Reverse lymphatic mapping: a new technique for maximizing safety in vascularized lymph node transfer. *Plast Reconstr Surg* 2015;**135**:277–85.
33. Zhang H, Chen W, Mu L, et al. The distribution of lymph nodes and their nutrient vessels in the groin region: an anatomic study for design of the lymph node flap. *Microsurgery* 2014;**34**:558-61.
34. Yamamoto T, Iida T, Yoshimatsu H, et al. Lymph flow restoration after tissue replantation and transfer: importance of lymph axiality and possibility of lymph flow reconstruction without lymph node transfer or lymphatic anastomosis. *Plast Reconstr Surg* 2018;**142**:796-804.
35. Cheville AL, Brinkmann DH, Ward SB, et al. The addition of SPECT/CT lymphoscintigraphy to breast cancer radiation planning spares lymph nodes critical for arm drainage. *Int J Radiat Oncol Biol Phys* 2013;**85**:971–7 15.