JOURNAL OF PLASTIC SURGERY AND HAND SURGERY
2022, VOL. 56, NO. 5, 261–269
https://doi.org/10.1080/2000656X.2021.1964980

ARTICLE

Preliminary outcomes of combined surgical approach for lower extremity lymphedema: supraclavicular lymph node transfer and lymphaticovenular anastomosis

Jae-Ho Chung, Yong-Jae Hwang, Seung-Ha Park and Eul-Sik Yoon

Department of Plastic and Reconstructive Surgery, Korea University Hospital, Seoul, Republic of Korea

ABSTRACT

Background: Vascularized lymph node transfer (VLNT) is a well-established surgical approach for treating lower extremity lymphedema (LEL). Since VLNT takes time to show effect, a combined approach with lymphaticovenular anastomosis (LVA) may be more advantageous to patients by inducing an immediate improvement. This study aims to describe our experience and evaluate the results of a combined approach.

Methods: In this retrospective review, we analyzed a total of 12 patients that underwent simultaneous supraclavicular VLNT and LVA for the treatment of secondary LEL with the ISL stage II or III. Patients who had a follow-up period of less than 12 months were excluded. The supraclavicular flap, including superficial lymphoid tissue as well as deep cervical nodes, was harvested and anastomosed to the posterior tibial vessels. The pre- and postoperative change of circumference difference ratios and LEL index were compared.

Results: All twelve flaps survived without re-exploration. An average of 2.3 LVAs were simultaneously performed. At 12.9 months of follow-up (range, 12–16 months), the postoperative mean circumference ratio was significantly improved than pre-operative in 10 cm above the knee ($7.9 \pm 7.2\%$ vs $15.0 \pm 7.6\%$, $p = 0.01$), 10 cm below the knee ($8.5 \pm 7.5\%$ vs $17.4 \pm 12.7\%$, $p = 0.03$) and lateral malleolus ($16.5 \pm 15.5\%$ vs $28.6 \pm 17.9\%$, $p = 0.03$). Also, the mean LEL index was decreased (preoperative 324.3 ± 53.0 vs postoperative 298.0 ± 44.6, $p = 0.242$) and eight patients showed improvement in LEL stage.

Conclusions: The combined approach showed a significant decrease in the circumference of LEL. Additional LVAs could reinforce the effect of a VLNT. Larger series with longer follow-up is needed to confirm our findings.

ARTICLE HISTORY
Received 14 October 2020
Revised 26 July 2021
Accepted 2 August 2021

KEYWORDS
Supraclavicular flap; lymph node transfer; lymphaticovenular anastomosis

LEVEL OF EVIDENCE
IV

Introduction

Secondary lymphedema in lower extremities occurs following gynecologic surgery in up to 18% of the patients [1]. When it occurs, the lymphatic fluid becomes stagnant, which cause tissue fibrosis, hypertrophic fat, destruction of lymphatic vessels, and ultimately leading to skin ulceration and infections [2]. It can be a debilitating disease to patients and has a dramatically negative effect on their quality of life [3]. However, there is still no cure for lymphedema and remains no consensus regarding a treatment approach.

In the past, invasive reductive procedures such as the Charles operation were performed, but it resulted in extensive scarring and substantial morbidity including significant blood loss or infection [2,4]. Therefore, in recent years, physiologic surgery, such as lymphaticovenular anastomosis (LVA) and vascularized lymph node transfer (VLNT), has become increasingly popular. Now, with the advent of the concept of supermicrosurgery, lymphatic surgery has become one of the most important realms of microsurgery.

So far, various donor sites for VLNT, such as the groin, submental and supraclavicular areas, have been well-described. In our institution, an axillary or groin VLNT was mainly used until 2017. However, in recent years, a supraclavicular flap has been used more frequently for a lymph node flap. Also, we usually perform multiple LVAs during a flap harvest. Since VLNT takes time to show effect, we believe that a combined approach with LVA may be more advantageous to patients by inducing an immediate improvement.

In this study, we present the outcomes of our patients with LEL who underwent simultaneous supraclavicular VLNT and LVA.

Material and method

Patients

Between November 2018 and October 2019, simultaneous supraclavicular VLNT and LVA were performed in 12 patients with secondary LEL. The patients (1) whose medical records were unclear

CONTACT Eul-Sik Yoon yesanam2@korea.ac.kr Department of Plastic and Reconstructive Surgery, Korea University Anam Hospital, 73, Inchon-ro, Seongbuk-gu, Seoul 02841, Republic of Korea

or without clinical photos and (2) with less than one year of follow-up were excluded. All supraclavicular VLNTs were performed by the senior author and all LVAs were performed by the first author. This retrospective analysis was approved by our facility's institutional review board (protocol number 2020AN0185).

Operative technique

Lymphaticovenular anastomosis

All procedures were performed under general anesthesia. After intradermal injection of 0.1–0.2 cc of indocyanine green (ICG, Dongindang Pharm, Sigheung, Korea) into each webspace of the toes, the course of the lymphatic vessel was identified with a hand held near-infrared cameras (Moment K®; IANC&S, Seoul, Korea or Fluobeam®; Fluoptics, France). If the lymphatic course was invisible in the patients with advanced-stage disease, the lymphatic path of the normal opposite lower limb was identified and the mirror image of the lymphatic course was marked. The primary sites of our choice for LVA were the dorsum of the foot, the ankle along the greater saphenous vein, and the superior edge of the knee. The incision site of the superior edge of the knee followed a previous report by Seki et al. [5]. In each site, a 3-cm-long incisions was usually made and the largest lymphatic vessel under the superficial fascia in the subcutaneous tissue was usually selected for the LVA. After identifying a venule of the appropriate size in the vicinity, LVA was performed with 11-0 nylon sutures. If there was a sufficiently large lymphatic vessel, side-to-end anastomosis was attempted first. In cases where the venule was larger than the lymphatic vessel, end-to-side anastomosis was performed. After all procedures, patency of the anastomosis was confirmed under an operating microscope by observing the movement of the lymph-blood border and filling of the venule across the anastomosis.

Supraclavicular lymph node transfer

In all patients, we used right side to avoid a potential injury to the thoracic duct on the left side. The entire supraclavicular lymph node transfer process was performed as previously described by Chang [6]. Before surgery, the anatomical landmarks of the posterior triangle, consisting of the clavicle, external jugular vein (EJV), and the lateral border of sternocleidomastoid(SCM) muscle, were marked up. Initially, a transverse incision 1 cm above the clavicle was made and the platysma muscle was divided. Then, meticulous dissection was performed at the space between the SCM muscle and the EJV. In this process, we tried to include as much superficial lymphoid tissue for lymph node flap as possible. Following the division of the omohyoid muscle, dissection proceeded lateral to the internal jugular vein (IJV). After the identification of the transcervical artery and vein, the adipose flap including supraclavicular lymph nodes was elevated based on the transcervical vessels above the plane of the scalene muscle.

In all cases, the posterior tibial artery and vein were selected as recipient vessels. After a 5–6-cm incision along the posterior border of the medial malleolus, the recipient vessels were identified by careful dissection. First, arterial anastomoses were performed in an end-to-side fashion. After confirming backflow, a venous anastomosis was also performed. The donor site was closed primarily with subcuticular and skin sutures without tension.

Postoperative care

Immediately after surgery, the operated limb was loosely compressed with an elastic bandage and elevated. A closed-suction drain was placed in the donor site, and removed when the drainage volume fell below 15 cc for two consecutive days. After one week, the long leg splint was removed and ambulation was encouraged. Flap circulation was monitored by color Doppler sonography (GE Logiq E9, Milwaukee, WI, USA) (Figure 1).

Outcome measurement

In our institution, limb circumference was measured at the following six points – the superior margin of the thigh, the superior edge of the patella, 10 cm above and below the patella, the lateral malleolus and the dorsum of the foot. The measurements were obtained by a surgeon or rehabilitation doctor at each follow-up in the outpatient clinic. We used two methods to evaluate the outcomes.

Circumference difference ratio

The comparison between the pre- and postoperative changes in ratio of circumference of the affected limb to the circumference of the healthy limb is the most commonly used method for assessing outcomes in lymphatic surgery. It is calculated by the following formula.

$$\text{Circumferencedifferenceratio}(\%) = \{(C_{lesion} - C_{unaffected})/C_{unaffected}\} \times 100$$

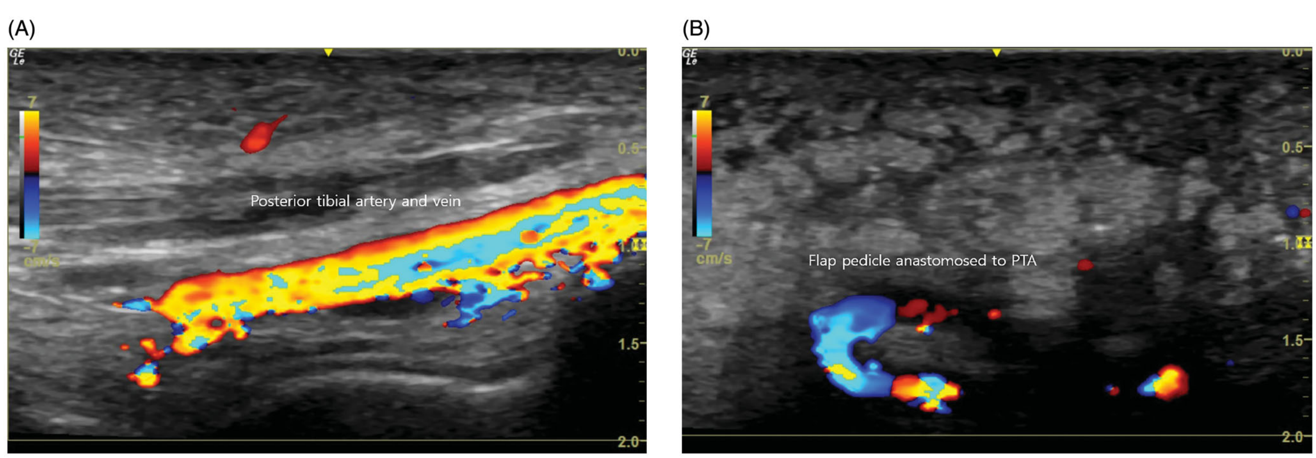

Figure 1. Flap circulation monitoring by color Doppler sonography (Patient no. 8). (A) Color Doppler flow image of the posterior tibial vessel. (B) Color Doppler flow image of the flap pedicle. The posterior tibial vessel and flap pedicle were easily identifiable. Arterial and venous blood flow of the supraclavicular VLNT was confirmed by Color flow duplex imaging. VLNT was deemed surviving functionally at 6 months after surgery.

Considering the site where the supraclavicular VLN was transferred, circumference difference ratio was compared at 10 cm above and below the knee and the lateral malleolus.

Lower extremity lymphedema (LEL) index

The LEL index, which was developed by Yamamoto et al., is widely used as a valid and reliable instrument in determining the severity of edema or the efficacy of treatment [7]. It reflects the body type of the patient, and showed a significant correlation with the clinical stage. The following established formula was used to calculate the LEL index.

$$\text{LELindex} = \sum_{k=1}^{5} {C_K}^2/\text{BMI}$$

The index was calculated by the sum of the squares of the circumference at five points and dividing it by patient's body mass index (BMI). The limb circumference at five points, except the value at the superior margin of the thigh, was used.

Statistical analyses

All statistical analyses were performed using SPSS version 24.0 software (IBM Corp., Redmond, WA, USA). In each analysis, the circumference measured at the latest follow-up was used for the postoperative circumference value. A Mann–Whiteny U test was performed for the comparisons of the outcomes. For all analyses, a value of $p < 0.05$ was considered statistically significant.

Result

Patient demographics

A total of 12 patients underwent a simultaneous supraclavicular VLNT and LVA between November 2018 and October 2019. The mean age of the patients was 61.2 years (range, 41–76 years) and the mean BMI was 26.4 (range, 20.8–32.4). By the classification of International Society of Lymphology (ISL), 11 patients had stage II clinical lymphedema, and one patient was classified with stage III. By the classification of ICG lymphography, 10 patients had stage IV lymphedema, and two patient was classified with stage V, which represents progressed lymphedema [8]. An average of 2.3 LVA was performed in 12 patients. Table 1 summarizes the patient characteristics and the site of the LVA.

With regard to VLNT, all flaps were harvested without a skin paddle. In all cases, the posterior tibial artery was chosen as the recipient artery and all anastomoses were performed in an end-to-side fashion. In the venous anastomoses, end-to-end anastomoses were performed in nine patients, and end-to-side anastomoses were performed in the other three patients. All twelve flaps survived without re-exploration. At a mean follow-up of 12.9 months (range, 12 months to 16 months), there was no chyle leak or donor site morbidity. There was one case of wound dehiscence at the donor site (No. 6), it was treated with delayed repair in the outpatient clinic.

Operative results

The postoperative mean circumference difference ratio was significantly improved than pre-operative in 10 cm above the knee (7.9 ± 7.2% vs 15.0 ± 7.6%, $p = 0.014$), 10 cm below the knee (8.5 ± 7.5% vs 17.4 ± 12.7%, $p = 0.033$) and lateral malleolus (16.5 ± 15.5% vs 28.6 ± 17.9%, $p = 0.028$) (Table 2). With regard to the LEL index, although it was not statistically significant, mean LEL index was decreased postoperatively (preoperative 324.3 ± 53.0 vs postoperative 298.0 ± 44.6, $p = 0.242$, Table 3). Of 12 patients, eight showed improvement in their LEL stage. Next, we describe our experience of two cases.

Case reports

Case 1 (patient 6)

A 69-year-old woman presented with bilateral LEL after a hysterectomy five years ago (Figure 2). She had undergone six sessions of chemotherapy and 28 sessions of radiotherapy. Although both sides showed the edematous symptoms, we decided to proceed with the surgery on the left side first, because it showed a worse condition. Three LVAs were performed at the dorsum of the foot, ankle, and the superior edge of the knee. Also, a VLNT from the right supraclavicular region was performed (Figure 3). The pre-operative circumference diameters were 47 cm and 43 cm at 10 cm above and below the patella, and 31 cm at lateral malleolus. The postoperative circumference diameters were improved to

Table 1. Patient demographics.

	Age	Sex	BMI	Etiology	ISL stage	ICG stage	Site	Symptom duration (years)	Follow-up (months)	No. of LV anastomosis	Site of LV anastomosis
1	50	F	24.0	Metastatic cancer	II	IV	Right	9	12	2	Ankle (×2)
2	57	F	31.4	Melanoma	II	IV	Left	2	14	2	Dorsum of foot, Ankle
3	54	F	24.1	Endometrial cancer	II	IV	Left	1	12	2	Ankle (×2)
4	61	F	26.1	Cervical cancer	II	IV	Right	12	12	3	Dorsum of foot, Ankle, Superior edge of the knee
5	71	F	21.4	Cervical cancer	II	IV	Right	1	16	3	Dorsum of foot, Ankle, Superior edge of the knee
6	69	F	29.3	Cervical cancer	II	IV	Left	5	14	3	Dorsum of foot, Ankle, Superior edge of the knee
7	63	F	32.4	Cervical cancer	III	V	Right	15	12	2	Dorsum of foot, Superior edge of the knee
8	41	F	26.3	Cervical cancer	II	IV	Left	3	15	3	Superior edge of the knee (×2), Ankle
9	76	M	25.1	Prostate cancer	II	V	Left	9	12	2	Superior edge of the knee, Ankle
10	73	F	28.8	Bladder cancer	II	IV	Left	1	12	3	Superior edge of the knee, Ankle (×2)
11	57	F	26.7	Cervical cancer	II	IV	Right	2	12	1	Ankle
12	62	F	20.8	Endometrial cancer	II	IV	Left	1	12	2	Ankle, Mid-calf
Mean ± SD	61.2 ± 10.2		26.4 ± 3.6					5.1 ± 4.9	12.9 ± 1.4	2.3 ± 0.7	

BMI: Body mass index; ISL: International Society of Lymphology; ICG: indocyanine green; LV: lymphaticovenular.

Table 2. The change of circumference difference ratio in 12 patients with lower limb lymphedema that underwent combined supraclavicular lymph node flap transfer and lymphaticovenular anastomosis.

Patient no.	Age (years)	Sex	ISL stage	ICG stage	Circumference difference ratio						Follow-up (months)
					Above-knee 10 cm		Below-knee 10 cm		Lateral malleolus		
					Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)	
1	50	F	II	IV	19.8	14.0	20.0	17.7	27.5	17.5	12
2	57	F	II	IV	18.4	8.5	5.4	4.1	28.6	9.1	14
3	54	F	II	IV	10.6	4.3	7.9	6.8	9.3	9.1	12
4	61	F	II	IV	16.7	11.1	11.4	2.6	31.0	4.6	12
5	71	F	II	IV	29.2	27.4	27.1	10.9	31.0	22.7	16
6	69	F	II	IV	11.0	2.1	11.7	2.6	10.7	3.7	14
7	63	F	III	V	3.9	3.0	42.9	21.6	36.2	32.1	12
8	41	F	II	IV	18.8	1.8	16.3	2.6	16.7	5.5	15
9	76	M	II	V	25.6	8.9	37.1	21.6	78.1	54.5	12
10	73	F	II	IV	10.5	5.9	19.4	4.7	30.0	4.8	12
11	57	F	II	IV	7.0	3.0	5.9	3.7	15.8	6.3	12
12	62	F	II	IV	8.9	4.7	3.2	3.2	28.2	27.8	12
Mean ± SD	61.2 ± 10.2				15.0 ± 7.6	7.9 ± 7.2	17.4 ± 12.7	8.5 ± 7.5	28.6 ± 17.9	16.5 ± 15.5	12.9 ± 1.4
p-Value					Pre vs Post $p = 0.014$*		Pre vs Post $p = 0.033$*		Pre vs Post $p = 0.028$*		

Mann–Whitney test was performed for evaluation of pre and postoperative volume difference at 10 cm above and below the patella, and the lateral malleolus.
ISL: International Society of Lymphology; ICG: indocyanine green; LV: lymphaticovenular; LEL: lower extremity lymphedema.
*Statistical significance.

Table 3. The change of LEL index in 12 patients with lower limb lymphedema that underwent combined supraclavicular lymph node flap transfer and lymphaticovenular anastomosis.

Patient no.	Age (years)	Sex	ISL stage	ICG stage	LEL index				Follow-up (months)
					Pre	LEL stage	Post	LEL stage	
1	50	F	II	IV	352.0	IV	329.5	III	12
2	57	F	II	IV	253.9	II	248.2	I	14
3	54	F	II	IV	326.9	III	282.9	II	12
4	61	F	II	IV	318.7	III	303.1	III	12
5	71	F	II	IV	341.8	III	330.0	III	16
6	69	F	II	IV	270.6	II	248.6	I	14
7	63	F	III	V	358.6	IV	333.5	III	12
8	41	F	II	IV	435.0	IV	347.6	III	15
9	76	M	II	V	380.0	IV	373.3	IV	12
10	73	F	II	IV	266.5	II	236.2	I	12
11	57	F	II	IV	302.9	III	263.9	II	12
12	62	F	II	IV	284.8	II	279.0	II	12
Mean ± SD	61.2 ± 10.2				324.3 ± 53.0		298.0 ± 44.6		12.9 ± 1.4
p-Value					Pre vs Post $p = 0.242$				

Mann–Whitney test was performed for evaluation of pre and postoperative LEL index.
ISL: International Society of Lymphology; ICG: indocyanine green; LV: lymphticovenular; LEL: lower extremity lymphedema.

46 cm, 39 cm and 26 cm at 14 months, respectively. At 14 months. The LEL index was also improved from 270.6 to 248.6 postoperatively.

Case 2 (patient 8)

A 41-year-old woman had left LEL after a hysterectomy three years ago (Figure 4). A year before visiting our clinic, she underwent LVA surgery at the ankle and knee levels at another hospital. However, a month after surgery, it had deteriorated and showed a repetitive lymphangitis. For treatment, a simultaneous supraclavicular VLNT and three LVAs were performed (Figure 5). LVAs were conducted at the ankle and the superior edge of the knee. The preoperative circumference diameters were 57 cm and 46.5 cm at 10 cm above and below the patella, and 32 cm at lateral maleollus. The postoperative circumference diameters were improved to 55 cm, 40 cm and 29 cm at 15 months, respectively. The LEL index was improved from 435.0 to 347.6 postoperatively. Also, the symptoms of lymphatic inflammation did not recur after surgery.

Discussion

The concept of a VLNT was introduced first by O'Brien and Chen in 1990 [9]. Since then, many animal and clinical trials have revealed that VLNT restored the lymphatic function [10–12]. Currently, there are two hypotheses commonly accepted as the principle of VLNT. First, the 'pump theory' suggests that the VLN flap absorbs the lymph fluid like a pump and drains it into the vein through natural lymphaticovenular connections inside the flap [13,14]. The other hypothesis, known as the 'lymphangiogenesis theory', suggests that the transferred lymph nodes have a high capacity for spontaneous regeneration, and improve the drainage by forming a bridge to the lymphatic pathway [15,16]. Recently, VLNT has gained consensus as a promising operative technique for lymphedema based on excellent outcomes [17].

There are variable options for donor sites for VLNT [18,19]. Although it is up to the surgeon's choice, the groin, submental and supraclavicular areas are common donor sites. Among them, a free supraclavicular flap with cervical lymph nodes was first

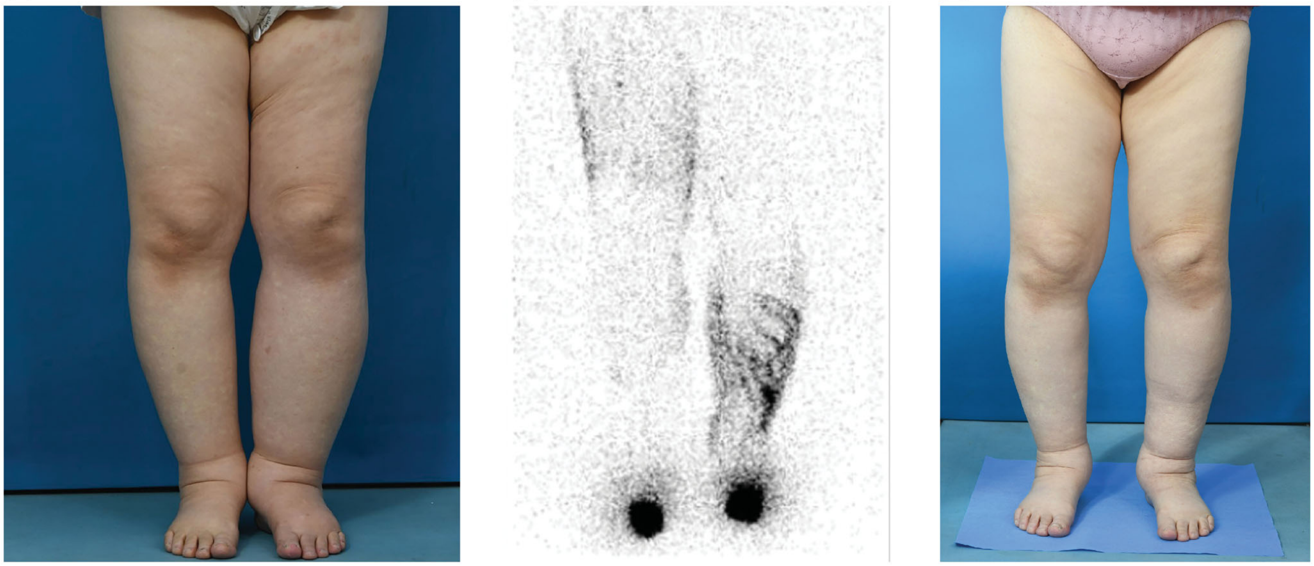

Figure 2. Pre- and postoperative clinical images of Patient no. 6. (A) A 69-year-old woman had suffered bilateral lower extremity lymphedema for 6 years following a hysterectomy. The LEL index at her left leg was 270.6 preoperatively. (B) Preoperative lymphoscintigraphy showed a significant amount of dermal back flow in both lower extremities, in which the left side showed a worse condition. (C) Simultaneous supraclavicular lymph node transfer and three lymphaticovenular anastomoses at the dorsum of foot, ankle and the superior edge of the knee were performed. At 14 months, her left LEL index was reduced to 248.6 postoperatively.

introduced as a potential donor site by Chang et al. [20] This flap has many advantages, including no risk of secondary lymphedema or nerve damage and a concealed scar. Some insisted that this type of flap seems to have lower lymph node quantity and an unreliable venous system compared to other donor sites [18,21,22]. We agree with their arguments somewhat, particularly the difficulty of dissection, but much of the data that have been published so far have already sufficiently proved the efficacy of this procedure [20,23–25]. Furthermore, there have been recent conflicting studies showing that the lymph node quantity in the supraclavicular flap was comparable to other types of VLN flaps in both cadaver and fresh human specimen studies [26,27]. Above all, most patients tended to be reluctant to have a long linear scar on the submental area. In general, Asian skin has a tendency toward scar formation and it is more prominent than Caucasians [28]. Thus, we used supraclavicular VLNT as a primary option for lymph node flap.

In our case series, we tried to include not only deep cervical nodes, but superficial lymphoid tissue as much as possible. Supraclavicular lymph nodes are anatomically divided into superficial and deep compartment, which is defined by the middle cervical fascia medially and supraclavicular nerves laterally [29]. By including as much lymphoid tissue as possible, it may have contributed to securing sufficient lymph node quantity for a positive on LEL index.

There are also many different opinions with regard to the recipient site for VLNT [13,24,25]. In general, the groin and popliteal fossa are considered a poor candidates for the recipient site, because it is theoretically unreasonable that the transferred lymph nodes absorb the lymph fluid against the force of gravity. Published literatures to date have suggested the dorsal crease of ankle as a main recipient site [3,5,27]. However, in this study, we used the posterior tibial artery as a recipient vessel due to several advantages. The posterior tibial artery is a traditionally used recipient site for the reconstruction of the lower extremity. It can preserve the distal circulation of the lower extremity when an anastomosis is performed in an end-to-side fashion. Also, it is advantageous to secure space for flap insetting, and leaves a less prominent scar than an anterior recipient site.

In another aspect, a recent report regarding the detailed anatomy of the lymphatics in the lower extremity using fresh human cadavers broadened our understanding of the lymphatic system [30]. According to Shinaoka's study, LVAs at the dorsum of the foot or the superior edge of the knee appear to be act on an anteromedial lymphatic pathway, while a supraclavicular VLNT at the posterior tibial vessel seems to be act on a posteromedial lymphatic pathway. Because most lymphatic vessels ran along anteromedial and posteromedial pathways, we presumed that our approach showed synergistic effects on both pathways. Therefore, it seems that the use of a posterior tibial vessel as a recipient would be an anatomically reasonable approach.

Now, it is well-established that LVA alone is less effective in lower extremities than upper extremities [31,32]. Similarly, we experienced a lower circumference reduction rate in the lower extremities than in the upper extremities in our previous study [33]. In the review of our patients, many patients who underwent LVA alone showed good results in the beginning, but returned to the preoperative state after six months to a year. While several centers reported good results for LEL with LVA alone [34], our viewpoint is that LVA alone could work in selected patients at an early stage. Because lower extremities are much larger and more gravity-dependent than upper extremities, the surgical approaches for the upper and lower extremities should be separate [23]. Therefore, we combined both a supraclavicular VLNT and LVAs to realize the benefits of both procedures.

In our opinion, additional LVAs at other sites could reinforce the effect of a VLNT. Based on an experimental study, a VLN flap takes at least three months to act as a pumping plant [9]. At this early period, the main effect of improvement effect comes from the LVA. Also, the recipient site for the flap is limited to the distal part of the limb as mentioned above. In this case, LVA could support the lymphatic flow, especially in a proximal lesion. Thus, we routinely performed as many LVAs as possible at multiple sites. LVA is a relatively minimally invasive procedure without donor-

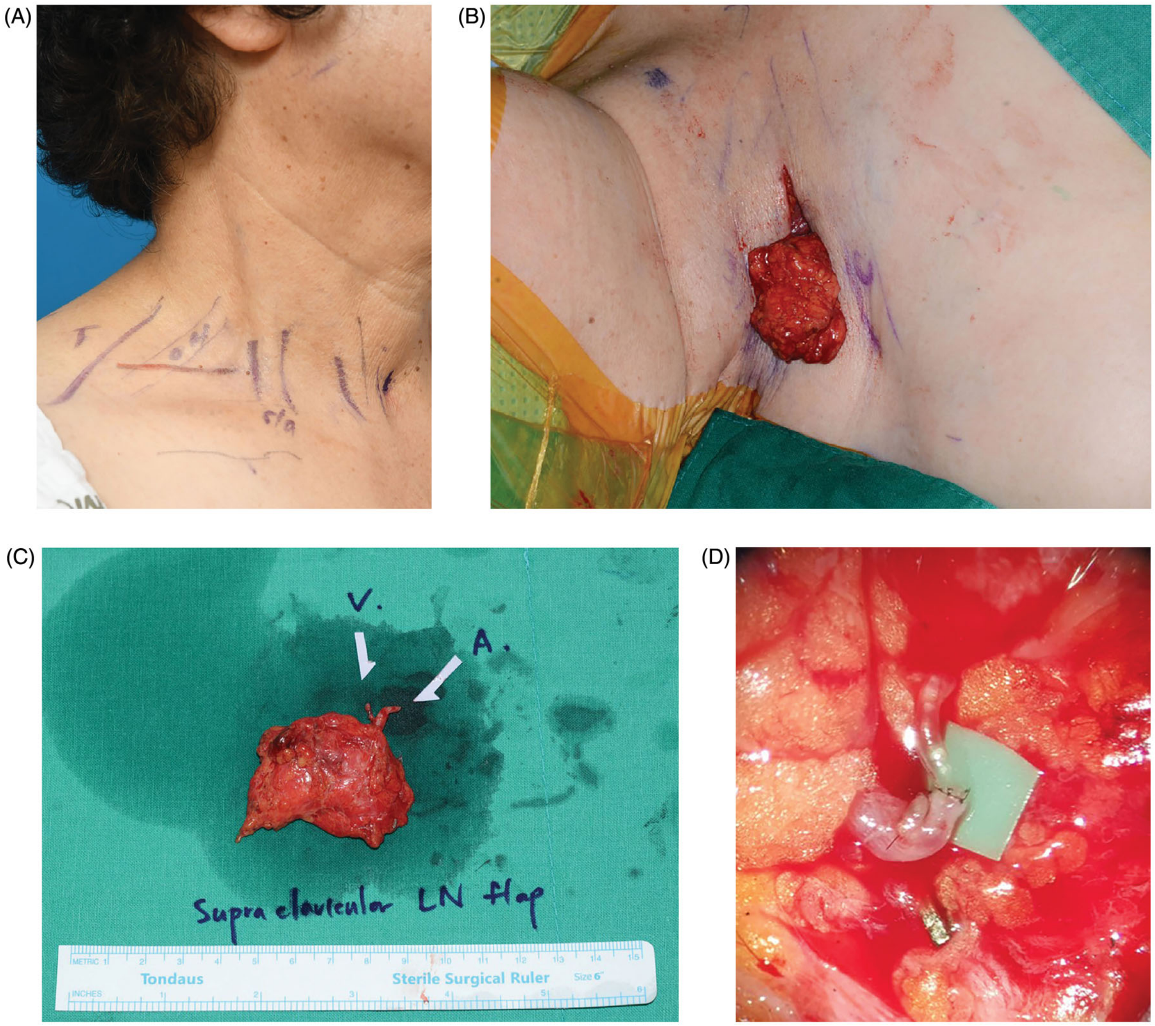

Figure 3. Intraoperative clinical image of Patient no. 6. (A) Preoperative design of the supraclavicular flap dissection. (B) Elevated state of the supraclavicular lymph node flap. (C) Supraclavicular lymph node flap with one artery and one vein. (D) Lymphaticovenular anastomosis in an end-to-end fashion at the ankle

site morbidity, so easily accessible during flap harvesting. We considered it a bridging technique for long-term improvement.

Meanwhile, there may be a question of whether LVA is useful in the late stage. As is well known, LVA is considered more effective in the early stages than the late-stage. In general, patients with late-stage disease with a significant dermal back flow are not candidates for LVA, because the lymphatic vessels become sclerotic, and cannot provide effective long-term results [2,35]. We also had a lot of difficulites in opration of a patient with stage III clinical lymphedema (Patient no. 7), because there were few healthy lymphatic vessels. Therefore, a combined approach may be more appropriate for patients with stage II clinical lymphedema, rather than patients with stage III.

In recent days, various imaging modalities including lymphoscintigraphy, SPECT/CT, MR lymphography, ICG lymphography, and ultrasonography have been introduced to preoperatively evaluate pathophysiological stage of LEL [36–39]. In the past, it was mainly up to microsurgeon's intuition and skill to find the lymphatic vessel and matching venule. However, with the advent of ICG lymphography, it was well known that operative results depends largely on the severity of lymphosclerosis [40]. In addition, it has been recommended to perfom LVA in the region showing linear pattern based on the finding of ICG lymphography [41,42]. In our institution, lymphoscintigraphy and ICG lymphography are currently the most commonly used modalities. Ultrasonography is also frequently used to find functional lymphatic vessels. Looking back on the development of lymphatic surgery over the past decade, it is expected that preoperative lymphatic mapping and objective postoperative evaluation using these imaging modalities will be more important in the future.

There are several techniques for flap monitoring, such as handheld Doppler, implantable Doppler, color duplex sonography and tissue oximetry. In the case of supraclavicular VLN flap, the most reliable monitoring tool might be an implantable Doppler. Teven et al. reported that implantable Doppler monitoring for vascularized lymph node transfers showed 100% sensitivity and 97.9% specificity [43]. However, there is no commercially available implantable Doppler in our country. Instead, we used color Doppler sonography for flap monitoring and could confirmed the intact blood flow to the buried flap (Figure 1). Color Doppler sonography is advantageous for finding the pulsation of vessels in real-time, even small perforators less than 0.5 mm [44].

There were several limitations in this study. First, it included a relatively few patients and used only single-center data. Second, we could not demonstrate the result of combined surgical approach when compared to the outcome of each intervention,

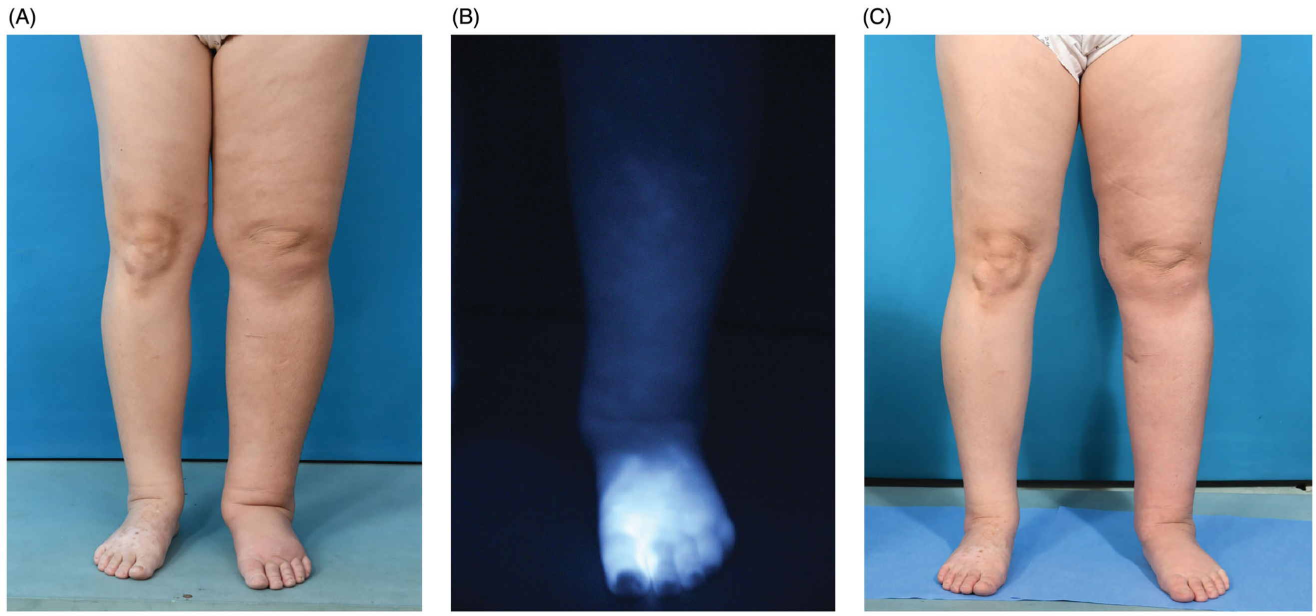

Figure 4. Pre- and postoperative clinical image of Patient no. 8. (A) A 41-year-old woman had suffered left lower extremity lymphedema for three years following a hysterectomy. She underwent the operation of lymphaticovenular anastomoses at the ankle and knee level at other hospital. However it deteriorated and showed a repetitive lymphangitis. The LEL index at her left leg was 430.5 preoperatively. (B) Image of indocyanine green lymphangiography showing few patent lymphatic vessels with severe dermal backflow. (C) Simultaneous supraclavicular lymph node transfer and three lymphaticovenular anastomoses at the ankle and the superior edge of the knee were performed At 15 months, her left LEL index was reduced to 347.6 postoperatively.

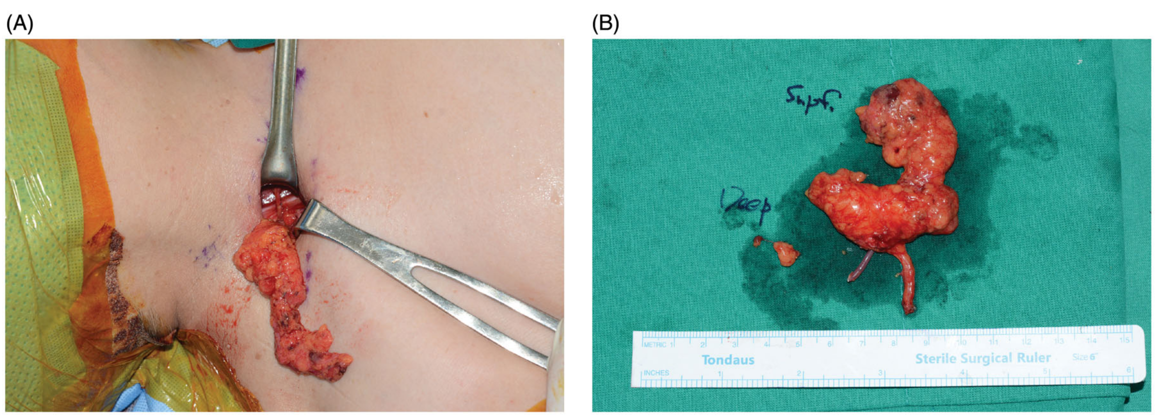

Figure 5. Intraoperative clinical image of Patient no. 8. (A) Elevated state of the supraclavicular lymph node flap. (B) Supraclavicular lymph node flap including both superficial and deep compartment.

LVA only or VLNT only. Because the number of patients with LEL in our institution is still small, we are trying to conduct those comparative analyses as a follow-up study. Third, the results were limited due to relatively short-term follow-ups. To determine if the VLN flap functions for a long-term period, further follow-up for more than two years may be required. In this respect, this study can be understood as a preliminary report, and the follow-up research is planned to report the long-term results. However, from the result of this study, our combined approach seems to be beneficial for patients with LEL, especially in stage II clinical lymphedema. Thus, it is expected that this study will serve as the basis for supporting the validity of a simultaneous supraclavicular VLN flap and LVA.

Conclusion

In patients with LEL, a combined approach with supraclavicular VLNT and LVA showed a significant decrease of circumference. In particular, the effect of supraclavicular VLNT could have been maximized by harvesting both superficial and deep compartment. Larger series with longer follow-up is needed to confirm our findings.

Acknowledgements

The first author (J. H. Chung) expressed his gratitude and respect to his mentor Dr. David W. Chang at Chicago University.

Disclosure statement

We have no potential conflicts of interest relevant to this article to report.

ORCID

Jae-Ho Chung http://orcid.org/0000-0002-8351-2444

References

[1] Ryan M, Stainton MC, Slaytor EK, et al. Aetiology and prevalence of lower limb lymphoedema following treatment for gynaecological cancer. Aust N Z J Obstet Gynaecol. 2003;43(2):148–151.
[2] Silva AK, Chang DW. Vascularized lymph node transfer and lymphovenous bypass: novel treatment strategies for symptomatic lymphedema. J Surg Oncol. 2016;113(8): 932–939.
[3] Kraft CT, Eiferman D, Jordan S, et al. Complications after vascularized jejunal mesenteric lymph node transfer: a 3-year experience. Microsurgery. 2019;39(6):497–501.
[4] Charles RH. Elephantiasis scroti. In: Latham A, English TC, editors. A system of treatment. Vol. 3. London: Churchill; 1912.
[5] Seki Y, Yamamoto T, Yoshimatsu H, et al. The Superior-Edge-of the-Knee incision method in lymphaticovenular anastomosis for lower extremity lymphedema. Plast Reconstr Surg. 2015;136(5):665e–675e.
[6] Ooi AS, Chang DW. 5-Step harvest of supraclavicular lymph nodes as vascularized free tissue transfer for treatment of lymphedema. J Surg Oncol. 2017;115(1):63–67.
[7] Yamamoto T, Matsuda N, Todokoro T, et al. Lower extremity lymphedema index: a simple method for severity evaluation of lower extremity lymphedema. Ann Plast Surg. 2011;67(6):637–640.
[8] Yamamoto T, Koshima I. ICG lymphography and its application. In: Cheng MH, Chang DW, Patel KM, editors. Principles and practice of lymphedema surgery. 2nd ed. Amsterdam: Elsevier; 2021. p. 52–58.
[9] Chen HC, O'Brien BM, Rogers IW, et al. Lymph node transfer for the treatment of obstructive lymphoedema in the canine model. Br J Plast Surg. 1990;43(5):578–586.
[10] Tobbia D, Semple J, Baker A, et al. Experimental assessment of autologous lymph node transplantation as treatment of postsurgical lymphedema. Plast Reconstr Surg. 2009;124(3):777–786.
[11] Lin CH, Ali R, Chen SC, et al. Vascularized groin lymph node transfer using the wrist as a recipient site for management of postmastectomy upper extremity lymphdedma. Plast Reconstr Surg. 2009;123(4):1265–1275.
[12] Becker C, Assouad J, Riquet M, et al. Postmastectomy lymphedema: long-term results following microsurgical lymph node transplantation. Ann Surg. 2006;243(3):313–315.
[13] Cheng MH, Huang JJ, Nguyen DH, et al. A novel approach to the treatment of lower extremity lymphedema by transferring a vascularized submental lymph node flap to the ankle. Gynecol Oncol. 2012;126(1):93–98.
[14] Mellor RH, Stanton AW, Menadue L, et al. Evidence for dermal angiogenesis in breast cancer related lymphedema demonstrated using dual-site fluorescence angiography. Microcirculation. 2002;9(3):207–219.
[15] 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(2):192e–1982.
[16] Patel KM, Lin CY, Cheng MH. From theory to evidence: long-term evaluation of the mechanism of action and flap integration of distal vascularized lymph node transfer. J Reconstr Micro. 2015;31:26–30.
[17] Scaglioni MF, Arvanitakis M, Chen YC, et al. Comprehensive review of vascularized lymph node transfers for lymphedema: outcomes and complications. Microsurgery. 2018;38(2):222–229.
[18] Patel KM, Chu SY, Huang JJ, et al. Preplanning vascularized lymph node transfer with duplex ultrasonography: an evaluation of 3 donor sites. Plast Reconstr Surg Glob Open. 2014;2(8):e193.
[19] Lasso JM, Pinilla C, Castellano M. New refinements in greater omentum free flap transfer for severe secondary lymphedema surgical treatment. Plast Reconstr Surg Glob Open. 2015;3(5):e387.
[20] Althubaiti GA, Crosby MA, Chang DW. Vascularized supraclavicular lymph node transfer for lower extremity lymphedema treatment. Plast Reconstr Surg. 2013;131(1): 133e–135e.
[21] Ito R, Lin MC, Cheng MH. Simultaneous bilateral submental lymph node flaps for lower limb lymphedema post leg Charles procedure. Plast Reconstr Surg Glob Open. 2015; 3(9):e513.
[22] Steinbacher J, Tinhofer IE, Meng S, et al. The surgical anatomy of the supraclavicular lymph node flap: a basis for the free vascularized lymph node transfer. J Surg Oncol. 2017; 115(1):60–62.
[23] Akita S, Mitsukawa N, Kuriyama M, et al. Comparison of vascularized supraclavicular lymph node transfer and lymphaticovenular anastomosis for advanced stage lower extremity lymphedema. Ann Plast Surg. 2015;74(5): 573–579.
[24] Maldonado AA, Chen R, Chang DW. The use of supraclavicular free flap with vascularized lymph node transfer for treatment of lymphedema: a prospective study of 100 consecutive cases. J Surg Oncol. 2017;115(1):68–71.
[25] Ciudad P, Agko M, Perez Coca JJ, et al. Comparison of long-term clinical outcomes among different vascularized lymph node transfers: 6-year experience of a single center's approach to the treatment of lymphedema. J Surg Oncol. 2017;116(6):671–682.
[26] Gerety PA, Pannucci CJ, Basta MN, et al. Lymph node content of supraclavicular and thoracodorsal-based axillary flaps for vascularized lymph node transfer. J Vasc Surg Venous Lymphat Disord. 2016;4(1):80–87.
[27] Liu HL, Chung JC. The lymph node content of supraclavicular lymph node flap: a histological study on fresh human specimens. Lymphat Res Biol. 2019;17(5):537–542.
[28] Lv K, Xia Z Chinese expert consensus on clinical prevention and treatment of scar. Burns Trauma. 2018;6:27.
[29] Visconti G, Tartaglione G, Bartoletti R, et al. Compartimental harvesting of dual lymph node flap from the right supraclavicular area for the treatment of lower extremity lymphedema: a case series. J Plast Reconstr Aesthet Surg. 2019;72(2):211–215.
[30] Shinaoka A, Koshimune S, Yamada K, et al. Correlations between tracer injection sites and lymphatic pathways in the leg: a near-Infrared fluorescence lymphography study. Plast Reconstr Surg. 2019;144(3):634–642.
[31] Chang DW, Suami H, Skoracki R. A prospective analysis of 100 consecutive lymphovenous bypass cases for treatment of extremity lymphedema. Plast Reconstr Surg. 2013;132(5): 1305–1314.
[32] O'Brien BM, Mellow CG, Khazanchi RK. Long-term results after microlymphaticovenous anastomosis for the treatment of obstructive lymphedema. Plast Reconstr Surg. 1990;85(4):562–572.

[33] Chung JH, Baek SO, Park HJ, et al. Efficacy and patient satisfaction regarding lymphovenous bypass with sleeve-in anastomosis for extremity lymphedema. Arch Plast Surg. 2019;46(1):46–56.
[34] Lee KT, Park JW, Mun GH. Serial two-year follow-up after lymphaticovenular anastomosis for the treatment of lymphedema. Microsurgery. 2017;37(7):763–770.
[35] Schaverien MV, Badash I, Patel KM, et al. Vascularized lymph node transfer for lymphedema. Semin Plast Surg. 2018;32(1):28–35.
[36] Yamamoto T, Narushima M, Doi K, et al. Characteristic indocyanine green lymphography findings in lower extremity lymphedema: the generation of a novel lymphedema severity staging system using dermal backflow patterns. Plast Reconstr Surg. 2011;127(5):1979–1986.
[37] Baulieu F, Bourgeois P, Maruani A, et al. Contributions of SPECT/CT imaging to the lymphoscintigraphic investigations of the lower limb lymphedema. Lymphology. 2013;46(3):106–119.
[38] Mitsumori LM, McDonald ES, Wilson GJ, et al. MR lymphangiography: how I do it. J Magn Reson Imaging. 2015;42(6):1465–1477.
[39] Hayashi A, Yamamoto T, Yoshimatsu H, et al. Ultrasound visualization of the lymphatic vessels in the lower leg. Microsurgery. 2016;36(5):397–401.
[40] Yamamoto T, Yamamoto N, Yoshimatsu H, et al. Factors associated with lymphosclerosis: an analysis on 962 lymphatic vessels. Plast Reconstr Surg. 2017;140(4):734–741.
[41] Yamamoto T, Narushima M, Koshima I. Lymphatic vessel diameter in female pelvic cancer-related lower extremity lymphedematous limbs. J Surg Oncol. 2018;117(6):1157–1163.
[42] Yamamoto T, Yamamoto N, Fuse Y, et al. Optimal sites for supermicrosurgical lymphaticovenular anastomosis: an analysis of lymphatic vessel detection rates on 840 surgical fields in lower extremity lymphedema patients. Plast Reconstr Surg. 2018;142(6):924e–930e.
[43] Teven CM, Ooi ASH, Inbal A, et al. Implantable Doppler monitoring of buried free flaps during vascularized lymph node transfer. J Surg Oncol. 2017;116(3):371–377.
[44] Tashiro K, Harima M, Kato M, et al. Preoperative color Doppler ultrasound assessment in planning of SCIP flaps. J Plast Reconstr Aesthet Surg. 2015;68(7):979–983.