Prevention and Treatment of Posttraumatic Lymphedema by Soft Tissue Reconstruction With Lymphatic Vessels Free Flap

An Observational Study

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Background: Extremities soft tissue damage may increase the risk of presenting posttraumatic lymphedema. This type of lymphedema is often ignored in trauma and reconstructive literature. We propose a microsurgical soft tissue reconstruction approach to prevent and/or treat posttraumatic lymphedema.

Patients and Methods: This is a multicentric retrospective observational study. Primary and secondary end points were to prevent and/or treat posttraumatic lymphedema and to achieve a stable soft tissue coverage, respectively. Patients with posttraumatic lymphedema and functional lymphatic channels in the indocyanine green lymphography, and patients with acute soft tissue trauma with lymphatic damage without lymphedema, either to treat and prevent lymphedema, respectively, were included as candidates for soft tissue reconstruction using a superficial circumflex iliac artery perforator lymphatic vessels free flap (SCIP-LV). Patients with no pitting edema, fibrosis, or nonfunctional lymphatics channels were excluded. The inguinal lymphatic anatomy was studied with indocyanine green lymphography for designing and in-setting the flap.

Results: Eleven patients underwent to microsurgical reconstruction with SCIP-LV free flap; minimum follow-up was 12 months. There were no flap failures. In the posttraumatic lymphedema group, the mean reduction of excess volume was 63.01%. Quality of life improved 51.85%. No patients in the acute trauma group developed lymphedema after the preventive microsurgical approach.

Conclusions: Soft tissue reconstruction with SCIP-LV free flap is an effective approach to prevent and treat posttraumatic lymphedema.

Key Words: lymphedema, posttraumatic lymphedema, extremity reconstruction, SCIP flap, microsurgery

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In upper and lower extremities, superficial and deep lymphatic systems are generally considered to work independently. Superficial system is considerably more important because it has a larger number of lymphatic vessels and carries most lymph volume of the limb.[1] Extremities soft tissue damage with disruption of the superficial lymphatic drainage system carry an increased risk of developing posttraumatic lymphedema.

Posttraumatic lymphedema is sparsely described in the literature and its incidence is unknown, but some authors have estimated up to 20% of persistent edema of the limbs after trauma.[2] Literature available is focused mainly on posttraumatic edema of the limbs (PEL), which is a broader diagnosis and does not necessarily involve a disruption of the lymphatic drainage, yet it still offers the best evidence to date for the pathophysiology of posttraumatic lymphedema.[2]

Literature regarding limb lymphedema widely describes this problem secondary to malignancies, which required lymph node (LN) dissection and radiotherapy, yet it rarely focuses on lymphedema secondary to trauma. Therefore, posttraumatic lymphedema is an underdiagnosed disease, which we have failed to properly recognize and treat (Supplemental Digital Content 1 http://links.lww.com/SAP/A536).

Recently, we have become aware of the importance of the role that the lymphatic system plays in trauma patients. We described the use of the Superficial Circumflex Iliac Artery Perforator Lymphatic Vessels (SCIP-LV) free flap for posttraumatic lymphedema treatment in a patient who underwent traditional reconstruction after a degloving injury.[3]

The aim of our study is to prevent and/or treat posttraumatic lymphedema achieving a stable soft tissue coverage, by doing a microsurgical reconstruction of critical lymphatic drainage areas using SCIP-LV free flap. In this article, we present a series of patients treated with this approach to restore the lymph flow.

PATIENTS AND METHODS

A retrospective observational study of a prospective database was performed in patients with limb soft tissue injury in critical lymphatic areas, in the Department of Plastic Surgery and Burns of Hospital del

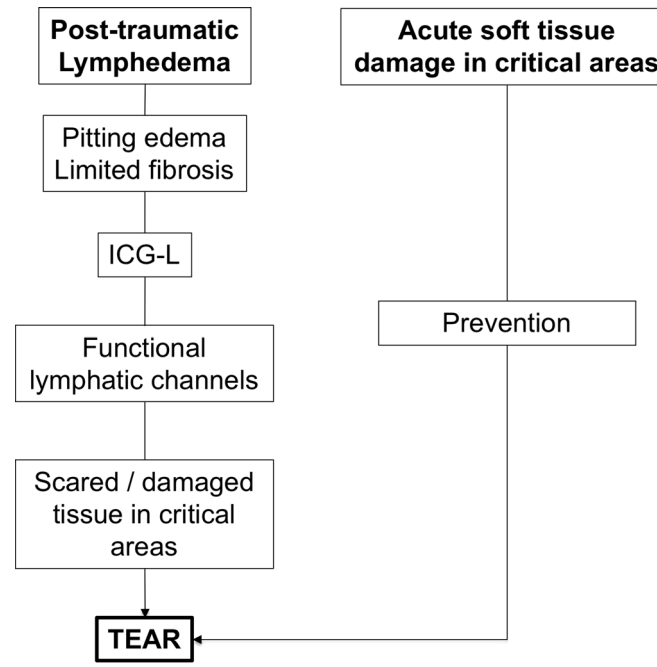

FIGURE 1. Total extremity anatomy reconstruction treatment algorithm.

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FIGURE 2. Inset of SCIP-LV in TEAR, locating the medial aspect of the flap in a position. full color online

Trabajador and Department of Plastic Surgery of Clínica Las Condes, between October 2017 and October 2019. This research was conducted by following the principles of the Declaration of Helsinki[4] and approved by the Scientific Ethics Committee. The authors adhere to standards for the reporting of diagnostic accuracy studies guidelines for diagnostic measure research (http://www.stard-statement.org). All patients signed a written consent authorizing their inclusion in the study.

Primary and secondary end points were to prevent and/or treat posttraumatic lymphedema achieving a stable soft tissue coverage, respectively. Patients with lymphedema, pitting edema, and limited fibrosis were considered candidates and underwent to functional assessment of the lymphatic system with indocyanine green lymphography (ICG-L). A linear pattern represents a linear fluorescent image of the lymphatic collectors usually observed in limbs with preserved lymphatic function. The dermal backflow patterns consist of splash, stardust, and diffuse patterns. In the splash pattern, scattered dye twinkling in tortuous lymphatic channels is observed. A stardust pattern demonstrates dimly luminous, spotted fluorescent signals. The diffuse pattern consists of widely distributed dye without twinkling or identifiable spots.[5] Inclusion criteria were lymphedema candidates with functional lymphatic channels (linear or splash pattern) and patients with acute soft tissue damage with lymphatic injury without lymphedema; they were proposed for soft tissue reconstruction to achieve the lymph flow restoration. Patients with no pitting edema, fibrosis, or nonfunctional lymphatics channels were excluded. The approach to restore the skin defect together with the lymphatic system function was named as total extremity anatomy reconstruction (TEAR; Fig. 1).

Clinical Assessment

Preoperative and postoperative assessment through a quality of life questionnaire[6] and measurements of both upper/lower limbs were performed in patients with posttraumatic lymphedema. Circumference perimeters were taken at different levels, before and after surgery with a tape measure: upper extremity, elbow, 5 cm above and below the elbow, wrist, and mid hand and lower extremity, superior border of the patella, 10 cm above the superior border of the patella, 10 cm below the inferior border of the patella, ankle, and mid foot. Extremities volumes were calculated according to the truncated cone formula.[7] To assess lymphedema improvement after surgical treatment, the percentage of excess volume (PEV) of the affected limb (PEV = volume of affected limb − volume of unaffected contralateral limb / volume of unaffected contralateral limb) and the reduction of excess volume (REV) between preoperative and postoperative (REV = [preoperative PEV − postoperative PEV] / preoperative PEV) were calculated.

Total Extremity Anatomy Reconstruction

In upper and lower extremities, there are higher lymphatic vessels density areas, such as anteromedial leg, medial aspect of elbow and knee, and medial aspect of arm and thigh.[8,9] In patients with soft tissue and lymphatic damage of those critical areas, with or without lymphedema at the moment of reconstruction, TEAR was performed to treat or prevent posttraumatic lymphedema, respectively.

Superficial circumflex iliac artery perforator-lymphatic vessels free flaps, as described in our previous report,[3] were performed by the same surgeon (N.P.) and used for TEAR. Computed tomography angiography[10] and augmented reality were performed for preoperative planning.[11] Lymphatic vessels anatomy and drainage of the SCIP-LV were studied injecting 0.1 mL of ICG lateral to the anterior superior iliac spine (Supplemental Digital Content 2 http://links.lww.com/SAP/A537) and considered for the design and inset of the flap, to restore the natural lymph flow of the limb. The flap was harvested including the deep fat layer based on the superficial (medial) branch of the superficial circumflex iliac artery (SCIA). The medial aspect of the flap was placed in a proximal location of the extremity defect and the lateral aspect in a distal location (Fig. 2).

No LNs were included in the flap; end-to-end perforator-to-perforator anastomosis or end-to-side anastomosis to a larger artery was performed with 9–0 or 10–0 nylon to 1 artery and 1/2 veins within the defect (Supplemental Digital Content 3 http://links.lww.com/SAP/A538). Deep and superficial fat layers of the flap and the recipient site were contacted with 4–0 Vicryl (Ethicon, NJ), and skin was closed with 4–0 nylon.

In acute soft tissue and lymphatic injury of critical areas, free flap reconstruction was performed using the TEAR approach to prevent posttraumatic lymphedema. Indocyanine green lymphography was performed for lymphatic vessels mapping and marked until the distal edge

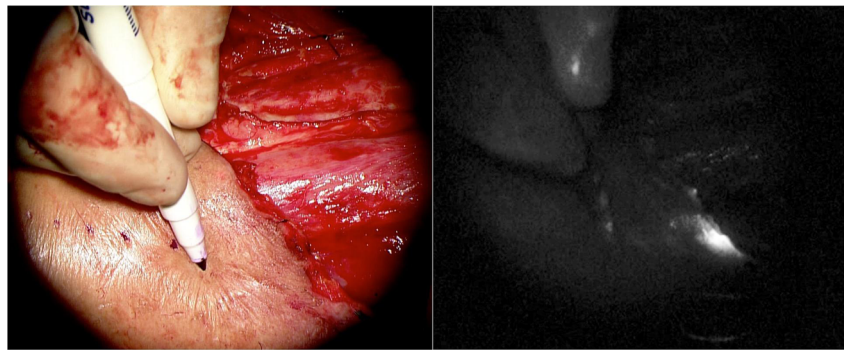

FIGURE 3. During TEAR operation, ICG-L is performed and lymphatic vessels are mapped until the distal edge of the wound. full color online

TABLE 1. Total Extremity Anatomy Reconstruction Approach in Acute Soft Tissue Injury of Lymphatic Critical Areas for Prevention Posttraumatic Lymphedema

	Sex	Extremity	Trauma	Reconstruction	Lymphedema
1	Male	Upper	Degloving injury	SCIP-LV free flap	No
2	Male	Upper	Spider bite	SCIP-LV free flap	No
3	Male	Lower	Degloving injury	SCIP-LV free flap	No
4	Female	Lower	Open tibial fracture	SCIP-LV free flap	No
5	Male	Lower	Open tibial fracture	SCIP-LV free flap	No
6	Male	Lower	Open tibial fracture	SCIP-LV free flap	No

wound. Scared and devitalized tissues were excised and the flap was tailored to the defect. Total extremity anatomy reconstruction was performed contacting the flap tissue with healthy recipient soft tissue, to provide a lymphatic vessel bridge through the flap.

RESULTS

Eleven patients were operated using TEAR approach during the study period; 6 patients with acute soft tissue and lymphatic injury (2 upper and 4 lower extremity cases) and 5 patients with posttraumatic lymphedema (3 upper and 2 lower extremities cases; Supplemental Digital Content 4 http://links.lww.com/SAP/A539).

Six patients with acute injury of lymphatic critical areas (degloving, open tibial fracture, skin necrosis secondary to spider bite—*cutaneous loxoscelism*) underwent to ICG-L study, and lymphatic vessels were mapped until the distal edge of the wound (Fig. 3). Excision of devitalized soft tissue, flap tailored to the defect, perforator-to-perforator anastomosis, and inset of the flap contacting healthy tissue considering the lymphatic flow direction were performed. No lymphedema was detected after 1-year follow-up (Supplemental Digital Content 5 http://links.lww.com/SAP/A540; Table 1).

Posttraumatic lymphedema was present in 5 patients secondary to degloving injuries (3), open tibial fracture (1), and necrotizing fasciitis (1). Indocyanine green lymphography was performed and lymphatic vessels were mapped until the border of the healthy skin. Scarred tissue excision, flap tailoring to the defect, vascular anastomosis, and inset of the flap contacting healthy tissue considering the lymphatic flow direction were performed (Fig. 4). There were no flap failures. The mean preoperative PEV was 19.29%. The postoperative PEV was 6.72%, and the mean REV was 63.01% at 12-month follow-up (Fig. 5; Table 2). Quality of life improved significantly after surgery, from a preoperative score of 54 of 100 to a postoperative score of 26 of 100 (improvement of 51.85%).

Postoperative ICG-L after TEAR approach showed functional lymphatic vessels up to the flap border, SCIP-LV flap ICG uptake, and functional lymphatic vessels proximal to the flap, demonstrating restoration of the natural lymph flow of the limb by this approach (Fig. 6). Moreover, extremity resurfacing, functionality, and an adequate contour were achieved, with a stable reconstruction in all cases, without flap failure.

DISCUSSION

To provide an optimal treatment is very important to consider the lymphatic system in the decisions-making algorithm for reconstruction. The use of the SCIP-LV free flap for soft tissue and lymphatic damage reconstruction is an effective approach to prevent and treat posttraumatic lymphedema.

Limb soft tissue damage with disruption of the superficial lymphatic drainage system increases the risk of developing posttraumatic lymphedema. In the upper extremity, lymph capillaries start at the fingertips and transition into collectors that run axially through the lateral and medial sides of each digit. Collector vessels continue their axial distribution through the dorsum of the hand and then travel across the circumference of the wrist and forearm up to the elbow after which they concentrate around the basilic vein along the anteromedial surface of the arm toward the axillary nodes.[8] In a similar distribution to the hand, the foot lymphatic system begins with collector vessels running on the

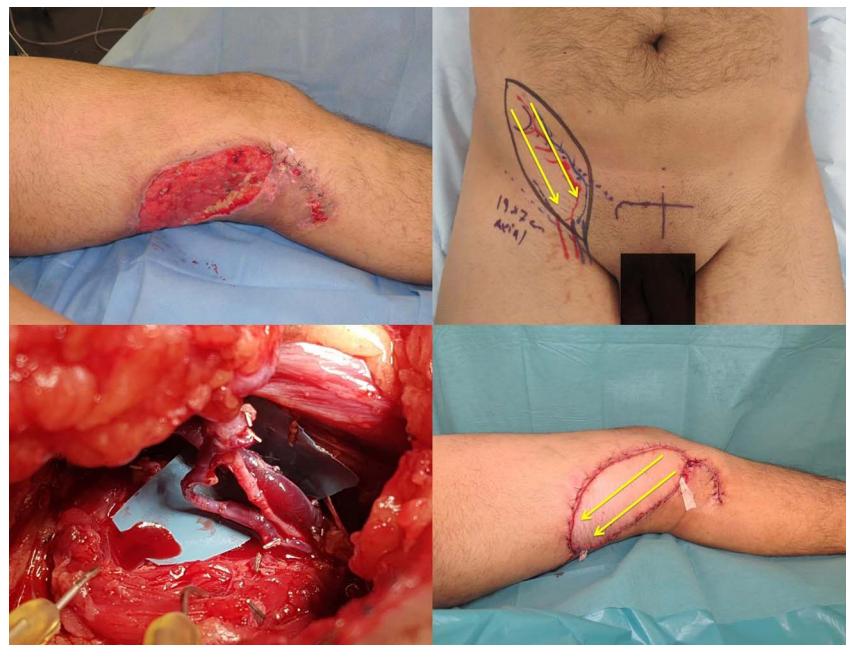

FIGURE 4. Inner knee degloving injury and acute lymphedema. Devitalized tissue excision, flap tailoring to the defect, vascular anastomosis, and inset of the flap contacting healthy tissue considering the lymphatic flow direction. full color online

FIGURE 5. Above: Left lower extremity lymphedema secondary degloving injury. Preoperative PEV was 20.12% and postoperative after one 1 was –1.35% (REV = 106.46%). Below: Right upper extremity lymphedema secondary degloving injury and skin graft. Preoperative PEV was 27.86% and postoperative after 1 year was 12.38% (REV = 55.6%). full color online

lateral and medial sides of each toe and then axially across the dorsum and anterior aspect of the ankle. Through the leg, knee, and thigh, the vessels concentrate on the anteromedial and posterior surfaces along the path of the great saphenous vein, with some running posterior on the thigh. Finally, the lymph drains toward the superficial inguinal nodes.[9]

Posttraumatic extremity lymphedema is sparsely described in the literature, and its incidence is unknown; however, there is an increasing group of patients with this condition. Szczesny et al[2] described the importance of lymphatic system alterations in PEL, which were studied with lymphocintigraphy. Their findings showed that even without physical disruption of the superficial lymphatic system, 100% of the patients studied experienced edema because of an increase in local lymphatic production. Local inflammation mechanisms are thought to contribute to this phenomenon. Only 24% of patients with posttraumatic edema showed venous thrombotic disease, which was previously thought to be a major contributor to PEL.[2] Lymphatic system interruption with dermal backflow was observed by Czepelenko[12,13] in the affected areas of patients with extensive soft tissue damage and multiple surgeries. In a

TABLE 2. Total Extremity Anatomy Reconstruction Approach for Posttraumatic Lymphedema Treatment

	Sex	Extremity	Trauma	Reconstruction	PEV Pre, %	LEQoLiS Preop	PEV Postop, %	LEQoLiS Postop	REV, %
1	Female	Upper	Degloving injury	SCIP-LV free flap	27.86	66/100	12.38	33/100	55.6
2	Female	Upper	Degloving injury	SCIP-LV free flap	19.25	50/100	5.55	22/100	71.17
3	Female	Upper	Necrotizing Fasciitis	SCIP-LV free flap	10.46	42/100	6.44	18/100	38.42
4	Male	Lower	Degloving injury	SCIP-LV free flap	20.12	60/100	(−) 1.35	0/100	106.46
5	Female	Lower	Open tibial fracture	SCIP-LV free flap	18.74	52/100	10.6	30/100	43.44
Mean					**19.29**	**54/100**	**6.72**	**26/100**	**63.01**

Mean values are presented in bold to differentiate them from the rest of the data.
LEQoLiS, lymphedema quality of life score.

more recent study by Lohrmann et al,[14] patients with PEL were evaluated with magnetic resonance lymphangiography demonstrating that 25% of limbs presented signs of lymphatic outflow obstruction.

The SCIP flap initially described by Koshima et al[15] in 2004 has gained widespread use in multiple reconstructive scenarios.[16–18] It has been described in lymphedema surgery by including inguinal LN in the flap for vascularized LN transfer with the potential risk of lymphedema of the donor site.[19] Recently, lymphedema prevention in oncologic surgery was reported by Gentileschi et al[20] with pedicled SCIP flap. The flap was elevated without any LN but with an abundance of lymphatic vessels (confirmed by ICG) to work as a bridge with the disconnected lymph vessels distal to the defect. It is important to note that no attempt was made to perform either lymfolymphatic or lymphovenous anastomosis.

Therefore, it is very important to know the lymphatic features of the different flaps that eventually could be used to cover a defect, to choose one that not only is rich in lymphatic vessels but also has the proper axiality of its drainage. This would allow a proper inset to recover the local lymphatic system flow.

This concept seems to be confirmed by the recent publication by Yamamoto et al[21] who did a retrospective analysis of tissue replantation and free flaps for limb reconstruction. He reported lymph flow restoration with ICG imaging in 9 (40%) of 22 flaps without performing lymfolymphatic or lymphovenous anastomosis. The importance of the axiality of the lymphatic system on inset was shown to be paramount to allow a proper lymph flow restoration because of the 1-way bump activity of healthy collector vessels within the transferred tissue.[21]

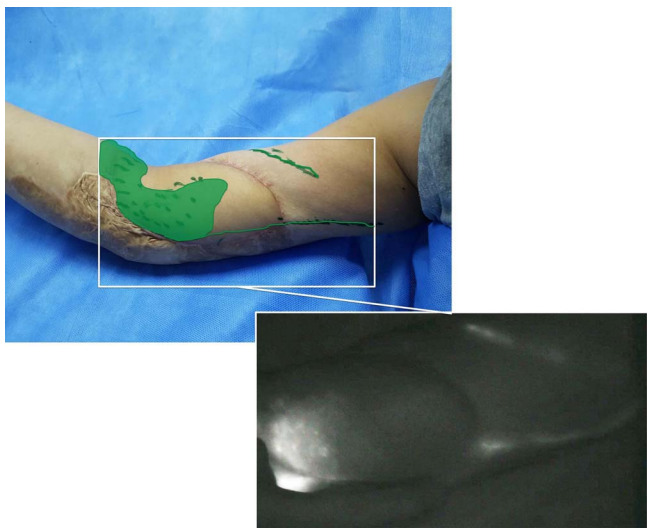

FIGURE 6. Postoperative ICG-L after TEAR approach. Functional lymphatic channels are seen up to the flap border, SCIP-LV flap ICG uptake, and functional lymphatic channels proximal to the flap, demonstrating a lymph flow restoration. full color online

According to the evidence, because of the abundance of lymphatic vessels and to the lymph flow direction parallel to its longer axis, we consider that the SCIP-LV flap is one of the ideal choices for soft tissue reconstruction of a traumatized limb in which we are planning to either treat or prevent posttraumatic lymphedema. In a previous publication, we have described our technique using the SCIP-LV free flap for successfully treating posttraumatic lymphedema presenting in patients who have undergone suboptimal reconstruction.[3]

Although our series is not very extensive, it is a prospective follow-up of cases that suggest a way to approach trauma associated with damage to the lymphatic system. Given the existing evidence and our results, we propose the concept of TEAR for soft tissue damage in critical areas of limb lymphatic drainage with the aim to prevent or treat posttraumatic lymphedema. We consider that this algorithm should be the new standard of care in limbs reconstruction, beyond the well-known goals of defect resurfacing, function and aesthetics, providing restoration of the damaged lymphatic system to avoid or treat posttraumatic lymphedema.

In conclusion, the TEAR approach for limb soft tissue and lymphatic damage of critical areas, with SCIP-LV free flap, may be an excellent option and an effective approach to prevent and treat posttraumatic lymphedema.

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