Hilar Vessels of the Submandibular and Upper Jugular Neck Lymph Nodes

Anatomical Study for Vascularized Lymph Node Transfer to Extremity Lymphedema

Pearlie W.W. Tan, MBBS, MRCS, Terence Goh, FAMS(Plast), Hideaki Nonomura, MD, and Bien-Keem Tan, FRCS

Objectives: Vascularized lymph node transfer for lymphedema is an emerging method of treatment. Vascularized lymph nodes have been harvested from a number of donor sites, that is, groin, axilla, and neck. There is a concern that harvesting nodes from the groin and axilla may lead to donor site lymphedema. This risk is greatly reduced in harvesting from the neck due to the abundant supply of lymph nodes here. In this cadaver study, we describe the submandibular and upper jugular groups of lymph nodes, demonstrate their hilar vessels, their source pedicles and drainage veins, quantified and qualified these groups of lymph nodes and their relationship to surrounding structures.

Methods: Five fresh adult cadaver necks (10 sides) were dissected looking at the submandibular and upper jugular neck nodes under the microscope. We carried out vascularized lymph node transfer of upper jugular nodes from the neck to the groin of 1 patient with stage II lower extremity lymphedema and transferred vascularized submandibular nodes from the neck to the upper arm in 1 patient with stage II upper extremity lymphedema.

Results: There was a mean of 3.2 (range, 1–5) lymph nodes in the submandibular group and a mean of 4.1 (range, 2–6) lymph nodes in the upper jugular group. The submandibular nodes were perfused by branches of the facial artery, that is, glandular and/or facial branches and/or submental artery in various permutations. The upper jugular nodes were perfused by the sternocleidomastoid artery, which branches from the superior thyroid artery (70%) or emerges directly from the external carotid artery (30%). Hilar veins were found to drain into surrounding larger draining tributary veins and ultimately into the internal jugular vein. At 1-year follow-up, there was a considerable decrease in girth circumference in our patients, no episodes of cellulitis after surgery, with subjective improvement in limb heaviness and skin pliability.

Conclusions: This knowledge of hilar blood supply will aid in transferring a lymphatic flap with intact microcirculation. When harvesting the submandibular nodes or upper jugular nodes, it is essential to harvest them based on their source pedicles, that is, facial artery and sternocleidomastoid artery, respectively, to supply live nodes to the recipient lymphedematous limb.

Key Words: lymphedema, vascularized lymph node transfer, neck, lymph nodes

(*Ann Plast Surg* 2016;76: 117–123)

Lymphedema is a condition characterized by progressive swelling and subsequent adipose tissue hypertrophy in later stages. This leads to several functional and social problems. There is constant discomfort of having a heavy limb, the social inconveniences of trying to conceal it, and an increased risk of recurrent infections from depressed local immunity of the affected limb. Vascularized lymph node transfer is an emerging method of lymphatic reconstruction in the surgical management of lymphedema. Studies have shown transferred lymph nodes lead to lymphatic regeneration with newly formed lymphatic vessels[1–3] On top of the improvement in limb girth, recent studies have shown functional regeneration of lymphatic vessels to lymph nodes sinuses that regulate immune cell homeostasis.[1] The T- and B-cell populations maintained in transplanted nodes make these nodes immunologically competent, lowering the long-term risk of recurrent infections and further scarring.

Vascularized lymph nodes can be harvested from a number of donor sites, that is, groin, axilla, and neck. There is a concern that harvesting nodes from the groin and axilla may lead to donor site lymphedema. This risk is obviated when harvesting from the neck due to the abundance of lymph nodes here. Lymphatic flaps from the neck have been based on the submental artery[4] with some case reports of lymph nodes based on the transverse cervical artery.[5] Whichever the pedicle, it is agreed, that if the selected vascular pedicle does not directly perfuse the lymph nodes, their function and ability to stimulate lymphogenesis will be hampered if not nullified.[6] We embarked on this cadaver project to study the hilar arterioles and venules of the submandibular and upper jugular nodes, traced them back to their source pedicles with the intent to determine the exact source of perfusion and venous drainage for lymphatic flap transfer. We report on our clinical application on 2 patients, 1 with upper limb lymphedema and 1 with lower limb lymphedema.

METHODS

Cadaver Study

The submandibular and upper jugular lymph nodes were studied in 5 formalin-fixed adult cadaver heads and necks (10 sides). The specimens were obtained from Science Care (Clinical Skills Laboratory, Singhealth Academy, Singapore) and stored in the freezer on arrival according to standard protocol. Vascular injections were carried out in 2 phases: Phase 1 started with irrigation of normal saline followed by formalin to prime the vessels. Phase 2 involved infusing diluted colored latex into the fine radicals of the arterial system, followed by a thicker latex-tapioca flour mixture for the larger vessels. Red latex was used for the arteries and blue for veins.

Dissection was carried out under loupe magnification of 3.5 and under a Leica microscope 16× magnification.

Lymph nodes bigger than 5 mm were isolated. Seen under the microscope, lymph nodes are characterized by their ruddy color, smooth surface, and firm consistency, in contrast to the surrounding soft lobular fat. The hilar vessels were traced in a retrograde manner to identify their source pedicle and draining veins. Number of lymph nodes, their size, and relationship to surrounding structures were recorded.

Clinical Application

We applied the anatomical information to 2 clinical cases. The first patient is a 63-year-old lady who presented with stage II (based on staging system of the International Society of Lymphology) bilateral lower limb lymphedema after radiotherapy for cervical cancer 20 years

Received October 25, 2014, and accepted for publication, after revision May 18, 2015.
From the Department of Plastic, Reconstructive and Aesthetic Surgery, Singapore General Hospital, Singapore.
Conflicts of interest and sources of funding: none declared.
Reprints: Pearlie WW Tan, MBBS, MRCS, Department of Plastic, Reconstructive and Aesthetic Surgery, Singapore General Hospital, Singapore 169608. E-mail: drpearlietan@gmail.com.

ISSN: 0148-7043/16/7601–0117
DOI: 10.1097/SAP.0000000000000582

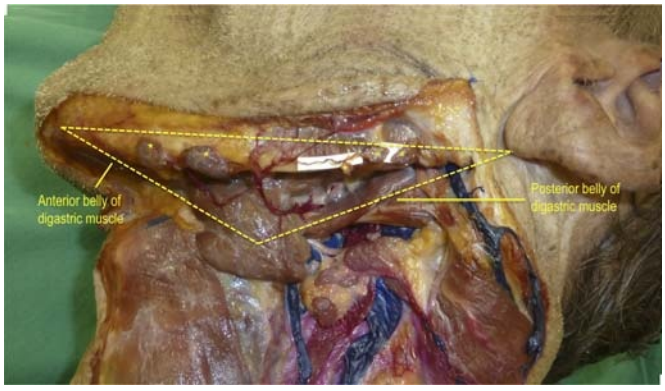

FIGURE 1. Submandibular nodes found in the "submandibular triangle," bordered by the inferior border of the mandible and the anterior and posterior bellies of the digastric muscle. Lymph nodes highlighted with yellow asterisks. Figure 1 can be viewed online in color at www.annalsplasticsurgery.com.

ago. Vascularized lymph nodes consisting of right side upper jugular nodes were transferred to the left groin. Anastomosis was carried out end-to-end between the superior thyroid artery (STA) and the superficial circumflex iliac artery, and venous anastomosis was carried out end-to-end between a large draining tributary vein from the lymphatic flap to the branch of anterior accessory saphenous vein.

The second case is a 52-year-old lady who presented with stage II lymphedema after right mastectomy and axillary clearance 13 years ago and failed conservative management. Vascularized lymph nodes consisting of the left submandibular nodes were transferred to the right upper medial arm. Anastomosis was carried out end-to-end between the facial artery and to a branch of the brachial artery supplying the biceps brachii, the facial vein was anastomosed end-to-end to one of the vena comitantes of the brachial artery, and the external jugular vein was anastomosed end-to-end to the other vena comitantes of the brachial artery.

For both patients, preoperative and postoperative limb volumes were measured and calculated using the Perometer (Perometer 350S, Juzo, Wuppertal, Germany).

Surgical Technique

The patient is positioned supine with a shoulder roll to extend the neck, this gives comfortable access to both the submandibular and upper jugular nodes. We choose either the submandibular or upper jugular nodes to harvest as the lymphatic flap after the field is exposed

TABLE 1. Submandibular Nodes Supplied by Branches of the Facial Artery After It Emerges From the External Carotid Artery, That Is, Glandular Branches, Facial Branches and the Submental Artery

		Submandibular Nodes					Upper Jugular Nodes				
Specimen	Side	Pedicle	Supplying Branches to Lymph Nodes	No. of Nodes >5mm in Size	Size of Nodes, mm	Pedicle Length, cm	Pedicle	Pedicle Arising From	No. of Nodes >5 mm in Size	Size of Nodes, mm	Pedicle Length, cm
1	R	Facial artery	Facial branches	2	12, 14	8.5	Sternocleidomastoid artery	STA	3	10, 10, 12	7.6
	L	Facial artery	Glandular branches	1	18	8.8	Sternocleidomastoid artery	ECA	5	10, 10, 10, 12, 15	8.8
2	R	Facial artery	Glandular and facial branches, submental artery	5	10, 18, 5, 10, 10	10.2	Sternocleidomastoid artery	STA	5	10, 12, 15, 20, 18	8.2
	L	Facial artery	Facial branches	3	8, 10, 6	10.4	Sternocleidomastoid artery	STA	2	15, 18	9.5
3	R	Facial artery	Glandular and facial branches, submental artery	4	10, 12, 8, 9	10.4	Sternocleidomastoid artery	STA	4	12, 10, 10, 12	8.5
	L	Facial artery	Facial branches, submental artery	4	8, 8, 5, 4	10.5	Sternocleidomastoid artery	ECA	4	8, 8, 11, 10	9
4	R	Facial artery	Glandular and facial branches, submental artery	5	5, 5, 6, 6, 8	10	Sternocleidomastoid artery	STA	6	8, 10, 10, 11, 11, 12	8.8
	L	Facial artery	Glandular branches	2	6, 8	9.6	Sternocleidomastoid artery	ECA	5	12, 12, 10, 8, 7	9.4
5	R	Facial artery	Glandular and facial branches	3	5, 5, 8	8.8	Sternocleidomastoid artery	STA	4	7, 8, 8, 6	10
	L	Facial artery	Glandular and facial branches	3	8, 10, 8	8.9	Sternocleidomastoid artery	STA	3	6, 5, 8	9.6
Average	—	—	—	3.2	8.5	9.6	—	—	4.1	10.4	8.9

Upper jugular nodes supplied by the sternocleidomastoid artery which originates from either the STA or directly from the ECA.

The facial artery pedicle was measured from its origin to the last node supplied.

For the length of the pedicle supplying the upper jugular nodes, if the sternocleidomastoid artery originated from the STA, the pedicle length was measured from the branching of the STA to the last node supplied. If the sternocleidomastoid artery pedicle originated from the external carotid artery, the length of the sternocleidomastoid artery to the last node supplied was measured as the pedicle length.

L indicates left; R, right.

depending on which area provides us the most number of vascularized nodes. When planning the neck incision, we avoided injuring the cervical branch of facial nerve by placing the skin crease incision 4.5 cm below the inferior border of the mandible, and after incising the deep cervical fascia, it is reflected so the nerve will be safely out of the way.

The sternocleidomastoid muscle is reflected laterally as we begin our search for the upper jugular nodes first. When available, the upper jugular nodes will be found lying adjacent to, or overlying the internal jugular vein, wedged between the submandibular gland medially and the reflected sternocleidomastoid muscle laterally. We visualize the hilar supply and check their origin. After confirming the pedicle origin, we then ligate it while encompassing all the viable nodes. A nerve to be aware of during harvest of upper jugular nodes is the external laryngeal nerve. It lies deep to the STA and is closely related to the branching hilar vessels. Handle delicately without crushing and avoid excessive retraction during dissection. Any injury will lead to a hoarse voice.

If the upper jugular nodes are unavailable, we proceed to locate the submandibular nodes higher in the neck. The submandibular lymph nodes are located in the submandibular triangle, which is formed by the inferior border of the mandible and the anterior and posterior bellies of the digastric muscle. The nodes can be found anteriorly in the submental area, that is, the submental nodes, or hugging the submandibular gland posteriorly, or nestled between the deep and superficial parts of the submandibular gland. The hilar vessels are found to be intimately related to the submandibular gland which has to be reflected and sometimes removed in piecemeal to reveal the tortuous course of the facial artery and its glandular branches. We visualize the hilar vessels to the lymph nodes early, and dissection is carried out toward the facial artery. We toggle between staying close to the pedicle and going "wide" around the nodes to ensure we safely capture the hilar vessels intact. We suggest dissection in this area to be done under visualization through the microscope.

Lymph nodes and hilar vessels are embedded in fat. The dissection should not denude the lymph nodes of all surrounding fatty tissue, a covering of fat should be left as protective padding to preserve the lymphatic vessels treading through it, this is important especially in light of a recent study which found high levels of growth factor (vascular endothelial growth factor-C) expression in the perinodal fat which plays an important role in subsequent lymphatic regeneration.[1] This flap must be handled delicately with no crushing of nodes or lymphatics.

Vascularized lymph nodes are "mini-flaps." Because the pedicles are usually smaller than the recipient vessels, there is a risk of overwhelming in-flow. To alleviate this situation, include more veins in the flap to relieve congestion with adequate drainage. After revascularization, healthy lymph nodes should appear pink and not a dark hue of purple.

Extremity Recipient Site

For treatment of the upper limb lymphedema case, incision was carried out along the upper most medial border of the arm to avoid the scarred areas of the previous axillary clearance. For the lower limb, we selected the groin as the area for recipient lymph nodes, due to the abundant of vessels for anastomosis, the more pliable skin here which aids in tension-free closure and for patient preference.

Vessel anastomosis was carried out with 9-0 and/or 10-0 Ethilon. Wounds are closed primarily over drains. To ensure transfer of viable lymph nodes, we routinely check flap perfusion with indocyanine green injected intravenously before ligating the source pedicle from the neck, and the circulation was checked again after revascularization at the recipient site.

Volumetric Analysis

The volume difference was measured using a Perometer (Perometer 350S, Juzo, Wuppertal, Germany). The Perometer is an optoelectrical imaging device designed specifically for measuring limb volume, circumference, contour, and cross-sectional area. It consists of a moveable frame that is moved over the extremity. In the frame, there are 2 measurement arrays placed in a 90 degree direction to each other which uses arrays of light switches built up by light emitting diodes to illuminate and scan an extremity in seconds. The Perometer automatically generates 2 contour pictures seen from the 2 sides, and the images and volume measurements are calculated in the computer.

RESULTS

Cadaver Study

Submandibular Lymph Nodes

We define the submandibular lymph nodes as nodes located in the submandibular triangle, which is formed by the inferior border of the mandible and the anterior and posterior bellies of the digastric muscle[10] (Fig. 1). An average of 3.2 (range, 2–5) lymph nodes were found here, average size of nodes was 8.5 mm (range, 5–18 mm) and average length of facial artery pedicle (measured from emergence off external carotid artery to last node supplied) was 9.6 cm (range, 8.5–10.5 cm) (Table 1).

Like olives hanging off an olive tree branch by its tiny stalks, the lymph nodes were attached to the facial artery via its hilar vessels. The facial artery has a tortuous course and supplies the lymph nodes via its branches, namely, the glandular (majority), facial, and submental artery, the latter being the terminal branch of the facial artery (Figs. 2 and 3). The superficial part of the submandibular gland was often reflected or dissected piecemeal to expose the hilar vessels (Fig. 4).

The lymph nodes here were supplied in various permutations by the glandular and facial branches of the facial artery and/or the submental artery. In 40% of specimens, the submental artery was seen contributing to hilar supply of the anterior-most nodes, that is, the submental lymph nodes, whereas in 60% of the specimens, there was no contribution from the submental artery, and lymph nodes were supplied by the other branches, that is, glandular and/or facial branches. In 4 specimens, we observed the feeding perforators to the overlying skin

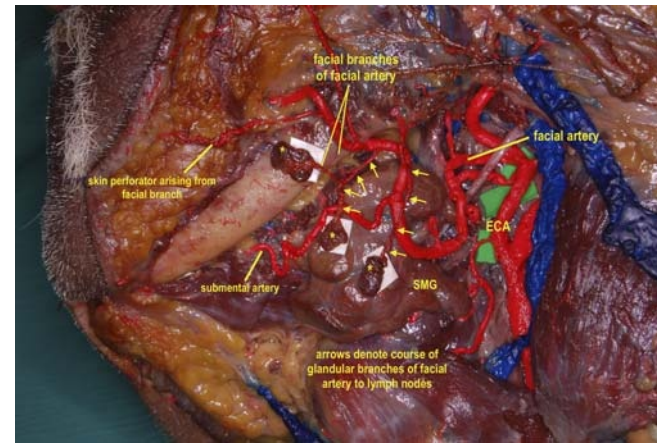

FIGURE 2. Submandibular lymph nodes highlighted with yellow asterisks. Some nodes found plastered to the submandibular gland and supplied by glandular branches of the facial artery (denoted by yellow arrows) and one node supplied by the facial branch of the facial artery. This specimen shows the skin perforator arising from the facial branch whereas some nodes were supplied separately by the glandular branches of the facial artery (lymph nodes highlighted with yellow asterisks; hilar vessels from glandular branches denoted by yellow arrows). ECA indicates external carotid artery; SMG, submandibular gland. Figure 2 can be viewed online in color at www.annalsplasticsurgery.com.

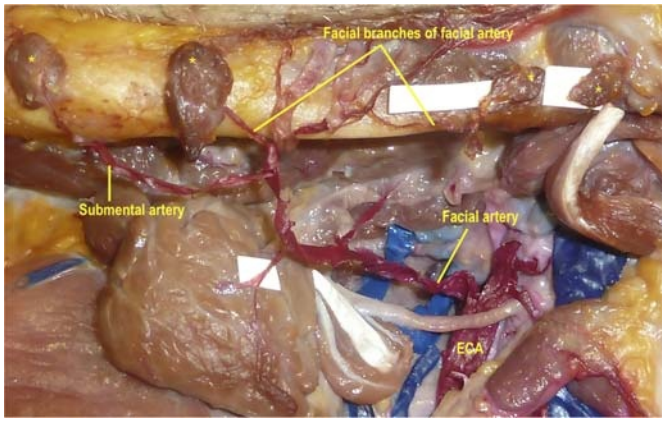

FIGURE 3. Specimen shows the facial branches and the submental artery supplying the lymph nodes (lymph nodes highlighted with yellow asterisks). Figure 3 can be viewed online in color at www.annalsplasticsurgery.com.

to be completely separate to the feeding branches to the lymph nodes. Figure 2 shows the overlying neck skin supplied by a perforator of the facial branch of the facial artery, with most of the lymph nodes supplied separately by glandular branches of the facial artery (Fig. 2). Therefore, when harvesting the nodes with a skin paddle, the hilar arterioles to the nodes should be visualized early, as during the sequential dissection from skin to facial artery, if carried out in an overly "skeletonizing" way close to the course of the pedicle, one may inadvertently sever the small hilar vessels to the nodes (Fig. 5).

Hilar veins drained into the facial vein and other surrounding draining tributary veins and ultimately into the internal jugular vein. Hilar arterioles and veins do not run in parallel. Hilar vessels are seen in arcades, whereas hilar venules diverge and drain into surrounding tributary veins.

Upper Jugular Lymph Nodes

We define the upper jugular nodes as nodes lying over or adjacent to the internal jugular vein, wedged between the submandibular

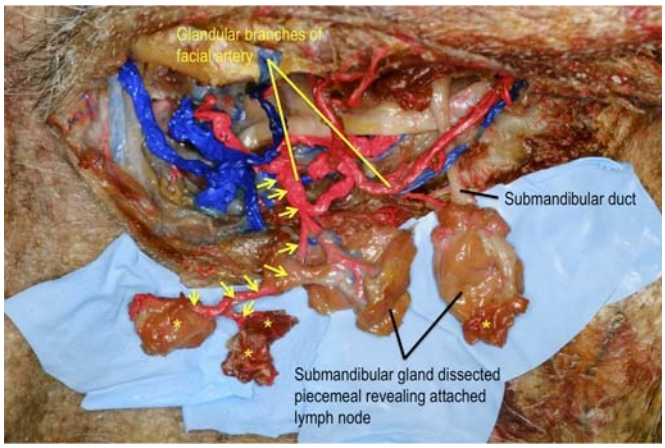

FIGURE 4. Submandibular gland dissected piecemeal revealing attached lymph node. All the nodes here supplied by glandular branches of the facial artery. Course of hilar arterioles is denoted by yellow arrows (lymph nodes highlighted with yellow asterisks). Figure 4 can be viewed online in color at www.annalsplasticsurgery.com.

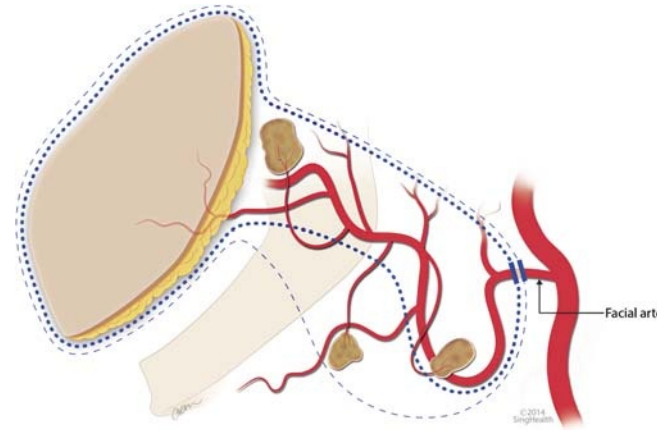

FIGURE 5. Perforator to overlying skin paddle separate from the branches supplying the lymph nodes. When dissection carried out from skin to pedicle, if dissection proceeded too close to the pedicle, that is, along dotted pathway, this will result in cutting through hilar blood supply. After visualizing hilar vessels, safe dissection can be carried out along dashed pathway. Figure 5 can be viewed online in color at www.annalsplasticsurgery.com.

gland medially and the reflected sternocleidomastoid laterally (Fig. 6). The lymph nodes here were supplied by the sternocleidomastoid artery which originated from the STA (70%) (Fig. 7A and B) or the external carotid artery directly (30%) (Fig. 8A and B). There was an average number of 4.1 (range, 2–6) lymph nodes here, average size was 10.4 mm (range, 5–20 mm) and average length of the flap pedicle was 8.9 cm (Table 1). In measuring the length of the pedicle, if the sternocleidomastoid artery originated from the STA, the pedicle length was measured from the STA to the last node supplied. If the sternocleidomastoid artery pedicle originated from the external carotid artery, the pedicle length was measured from the sternocleidomastoid artery to the last node supplied. The 2 variations of where the sternocleidomastoid artery originates are important to visualize during harvest.

As the sternocleidomastoid artery travelled laterally to the inner surface of the sternocleidomastoid muscle, a fine cascade of branching arterioles supplied the lymph nodes (Fig. 9). When harvesting these nodes, if the sternocleidomastoid artery branches from

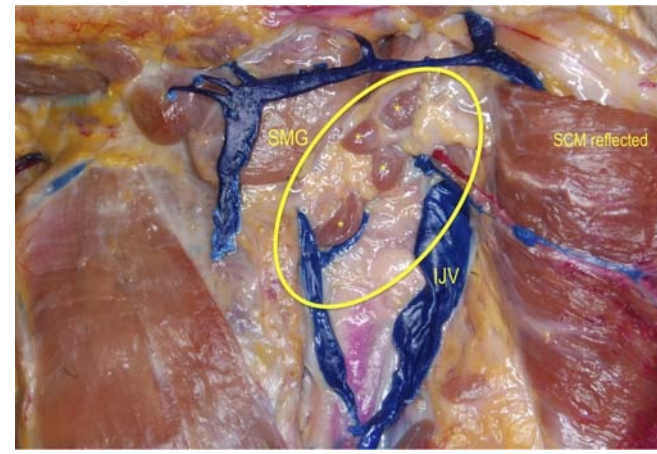

FIGURE 6. Upper jugular nodes found lying adjacent or overlying the IJV and lateral to the submandibular gland (SMG). (Lymph nodes highlighted with yellow asterisks). IJV indicates internal jugular vein. Figure 6 can be viewed online in color at www.annalsplasticsurgery.com.

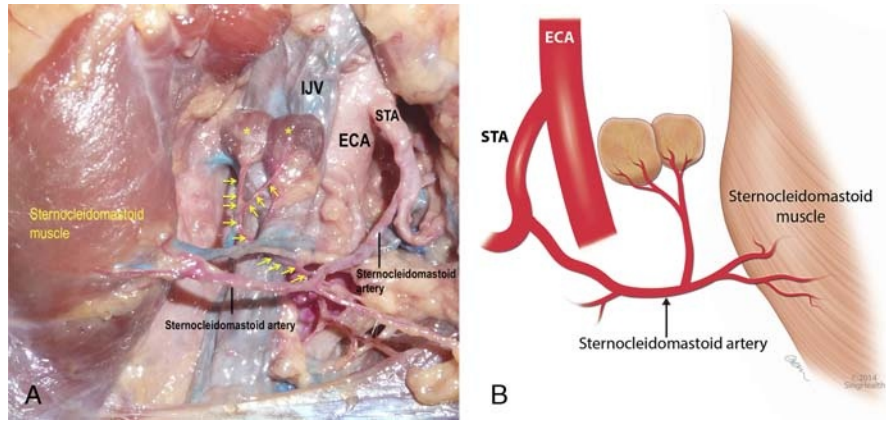

FIGURE 7. A, The sternocleidomastoid artery is a branch of the STA in 70% of dissections. The hilar arterioles branching from the sternocleidomastoid artery denoted by yellow arrows (lymph nodes highlighted with yellow asterisks). B, Schematic diagram illustrating hilar vessels from the sternocleidomastoid artery originating from the STA. Figure 7 can be viewed online in color at www.annalsplasticsurgery.com.

the STA, the STA can be used as the flap pedicle and the medial branches ligated. If the sternocleidomastoid artery branches directly from the external carotid artery, only this needs to be ligated as the pedicle (Figs. 7B and 8B).

Hilar veins drained into surrounding draining tributary veins and ultimately into the internal jugular vein (Fig. 10). Hilar arterioles and veins do not run in parallel. Hilar vessels are seen in arcades, whereas hilar venules diverge and drain into surrounding tributary veins.

Clinical Application

Case 1

At follow-up 1 year after the surgery, the first case had a remarkable decrease shown on volumetric analysis. Preoperative volume of the left affected extremity was 10610 mL before surgery which decreased to 7958 mL 1 year after the surgery, representing a 25% reduction in volume. There was no donor site morbidity, the scar healed nicely along the neck crease. The recipient site scar was easily concealed by clothes. We routinely commence compression garments 1 week after the surgery, and patients are taught to perform their own massage. This patient started ambulation 4 weeks after the surgery. She was very satisfied with the result and requested a repeat procedure for the unoperated right lower extremity 6 months later. There were no episodes of cellulitis of the limb after surgery (Fig. 11).

Case 2

At follow-up 1 year after the surgery, the second case had an initial remarkable decrease in volume to the affected right upper extremity shown on volumetric analysis. The preoperative volume was 2739 mL, which decreased to 1805 mL 2 months after surgery (34% volume reduction) and was measured to be 2223 mL 1 year after surgery. Overall, she had a 19 % reduction in volume at 1 year. There was no donor site morbidity. The recipient site scar had healed nicely along the upper medial arm which was easily concealed with a short sleeve blouse. We started her on compression garments 1 week after the surgery, and she was also taught to perform massage on her own. This patient started gentle range-of-motion exercises 3 weeks after surgery. She reported subjective improvement with the arm feeling lighter and

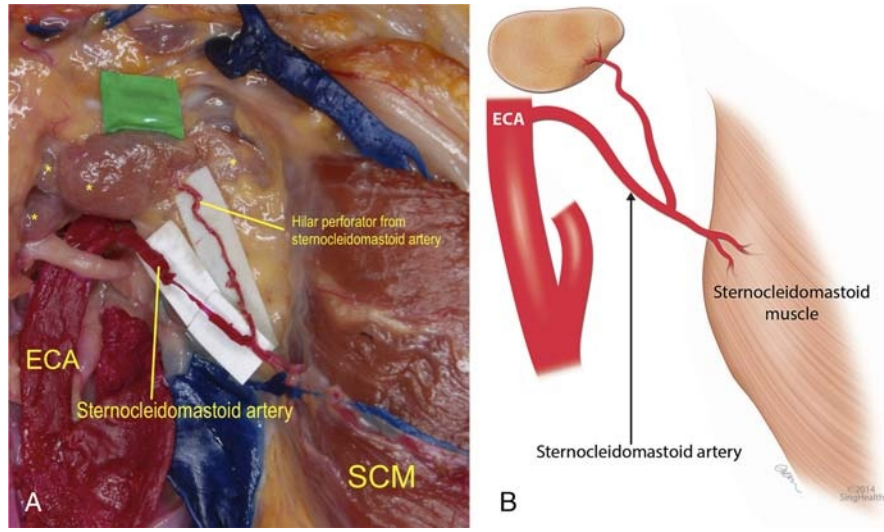

FIGURE 8. A, The sternocleidomastoid artery branches directly from the external carotid artery in 30% of dissections (lymph nodes highlighted with yellow asterisks). B, Schematic diagram illustrating hilar vessels from the sternocleidomastoid artery originating from the ECA. SCM indicates sternocleidomastoid muscle. Figure 8 can be viewed online in color at www.annalsplasticsurgery.com.

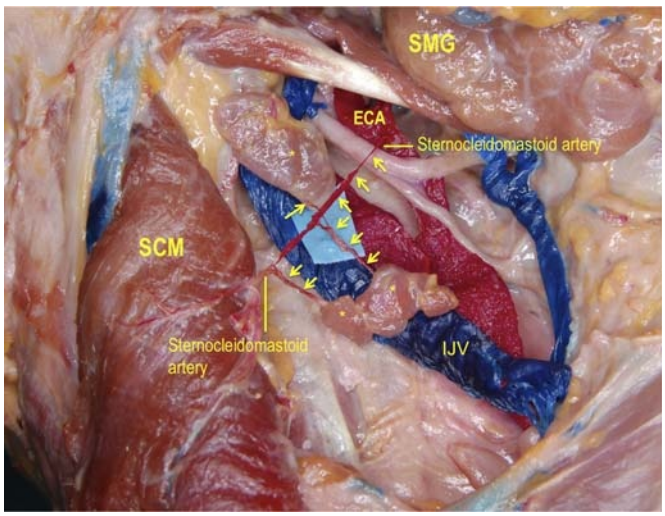

FIGURE 9. The sternocleidomastoid artery travels laterally to the inner surface of the sternocleidomastoid muscle, providing a cascade of branching arterioles to the lymph nodes (lymph nodes highlighted with yellow asterisks. Hilar branches denoted by yellow arrows). Figure 9 can be viewed online in color at www.annalsplasticsurgery.com.

skin felt softer overall; however, she requested for lymphaticovenous anastomoses for further reduction. There were no episodes of cellulitis after surgery (Fig. 12).

DISCUSSION

The importance of microsurgically anastomosed vascularized lymph nodes was highlighted early on in the classic experiment by Tobia et al[2] on lymphedematous sheep limbs, when the outcome of a transplanted lymph node (avascular graft/node transplant) was compared to that of a vascularized lymph node transferred with microsurgical anastomosis and showed the superior results of the latter. The group that underwent vascularized lymph node transfer had serum albumin transport levels approaching that of the normal control group versus the avascular nodal group whose serum albumin transport rate fell significantly below both groups. This highlighted the importance of transferring viable nodes with an intact circulation. With more vascularized lymph node operations being performed, it is necessary to understand the blood supply of lymphatic flaps. The neck serves as an ideal donor site, with its abundant lymph nodes, little risk of developing donor site lymphedema and the scar can be well hidden along natural skin ceases. Presently, there is no anatomical study delineating the detailed blood supply to the lymph nodes in the neck. Our study clearly illustrates the hilar vessels supplying the lymph nodes of the submental, submandibular, and upper jugular group of nodes and traced their origins.

Our anatomic study showed an average of 3.2 (range, 2–5) lymph nodes found in the submandibular area. The lymph nodes were supplied in various permutations by the glandular and facial branches of the facial artery and/or the submental artery. In 40% of the specimens, the submental artery was seen contributing to hilar supply of the anterior-most nodes, that is, the submental lymph nodes, whereas in 60% of the specimens, there was no contribution from the submental artery, and lymph nodes were supplied by other branches of the facial artery, that is, glandular and/or facial branches. Therefore, the hilar supply to the nodes must be checked early to preserve supplying hilar vessels to visualized nodes while safely ligating the inconsequential vessels. Neck skin overlying these nodes is supplied by perforators from the submental artery or the facial artery. In 4 of our cadaver specimens, the hilar vessels and the cutaneous perforator were derived from separate

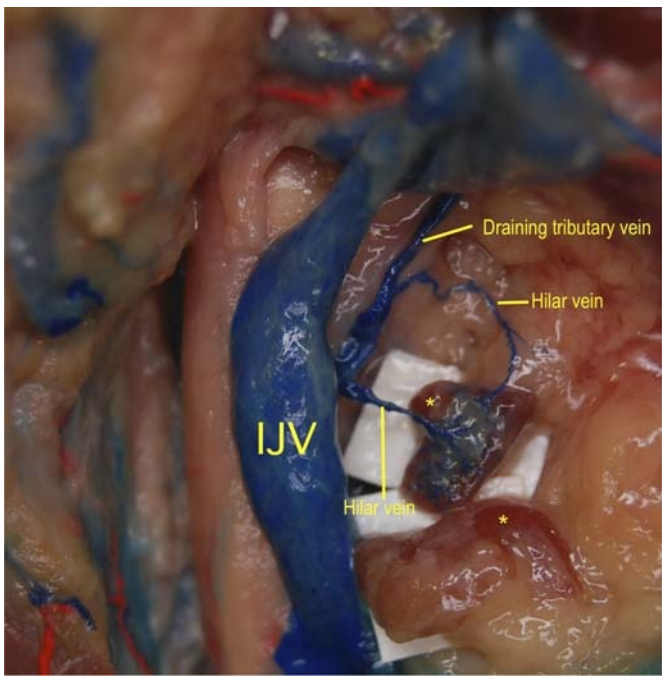

FIGURE 10. Hilar veins found to be draining into surrounding draining tributary veins and ultimately into the IJV.

FIGURE 11. Case 1. A 63-year-old woman presented with bilateral lower limb lymphedema of more than 10 years duration after radiotherapy for cervical cancer 20 years ago. Vascularized lymph nodes consisting of right-sided upper jugular nodes were transferred to the left groin. Anastomosis was carried out end-to-end between the superior thyroid artery and the superficial circumflex iliac artery, venous anastomosis was carried out end-to-end between a large draining tributary vein from the lymphatic flap to the anterior accessory saphenous vein. Postoperatively, there were subjective and objective improvements. Volumetric analysis showed the affected limb volume to be 10610 mL before surgery which decreased to 7958 mL 1 year after surgery, representing a 25% volume reduction.

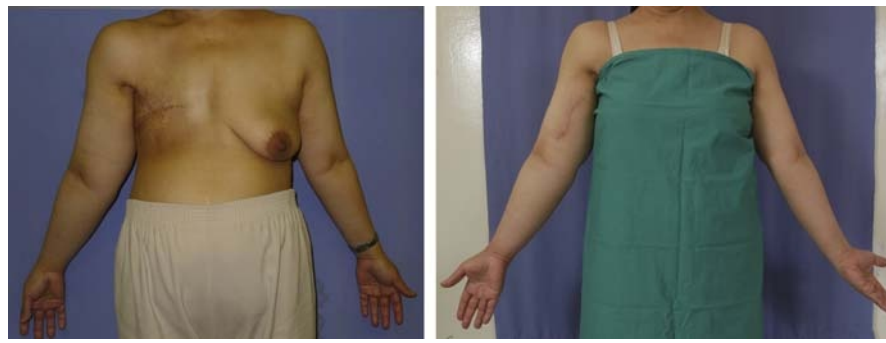

FIGURE 12. Case 2. A 52-year-old woman underwent mastectomy and axillary clearance for right breast cancer 13 years ago, presented with upper limb lymphedema resistant to conservative management. Vascularized lymph nodes consisting of the left submandibular nodes were transferred to the right upper medial arm. Anastomosis was carried out end-to-end between the facial artery and to a branch of the brachial artery supplying the biceps brachii, the facial vein was anastomosed end-to-end to one of the vena comitantes of the brachial artery and the external jugular vein was anastomosed end-to-end to the other vena comitantes of the brachial artery. Postoperative recovery was uneventful, and there were both subjective and objective improvements. Volumetric analysis showed the affected limb volume to be 2739 mL before surgery which decreased to 1805 mL 2 months after surgery and 2223 mL 1 year after surgery, representing a 19% volume reduction at 1 year.

branches of the facial artery (Fig. 2). Visualizing the hilar vessels early benefits the surgeon, so he is aware of the pattern of skin supply and lymph nodes supply. He will then know when to stay close to the facial artery pedicle, and when to go "wide" to capture the different branches supplying both the skin and the lymph nodes (Fig. 5).

There was an average of 4.1 (range, 2–6) lymph nodes in the upper jugular area. We found 2 variations in the origin of the sternocleidomastoid artery supplying the upper jugular nodes. It originated from the STA in 70% of the specimens or directly from the external carotid artery in 30% of the specimens. This variation of origin is important to appreciate. During harvest, if the sternocleidomastoid artery is found to be emanating from the STA, the STA will be ligated as the flap pedicle. If the sternocleidomastoid artery originates directly from the external carotid artery, then this vessel itself is the designated flap pedicle (Figs. 7B and 8B). When ligating the sternocleidomastoid artery distally, do so as close to the sternocleidomastoid muscle to capture all the intervening hilar arterioles between its origin and the muscle (Fig. 9).

Another area of debate among surgeons managing lymphedema is the inclusion of the skin paddle of this lymph node flap. Some believe the skin paddle is necessary, whereas others do not routinely incorporate a skin paddle.[7] As the recipient lymphedematous limb usually has fibrotic and inelastic skin with edges that spring apart after an incision is made, direct skin closure may compromise the underlying pedicle so a skin paddle stitched to the edge of the wound aids in tension-free closure. Having a skin paddle will also allow flap monitoring. We decide on the incorporation of a skin paddle according to the extent of fibrosis of the recipient site. In very fibrotic tissue, we use the skin paddle to aid in closure; if the recipient area has supple surrounding tissue, we may not include a skin paddle. As shown by Tobia et al, lymphatic regeneration occurred from a vascularized lymph node on its own, without overlying skin.[2] In addition, an illuminating study by Cheng et al, who studied the mechanism of lymphatic drainage of vascularized lymph node flaps using indocyanine green imaging, showed that when the nodes themselves were injected, drainage into the pedicle vein of the flap was rapid, drainage was slower when the flaps were injected at the edge of the flap, that is, in the skin, and slowest when non–lymph node flaps were injected, demonstrating that the lymph nodes were the most important element in the mechanism of lymph node drainage.[8] We feel that although this was not the focus of our present study, it is an area deserving further research.

Our 1 year results have shown considerable decrease in girth circumference in our patients, no episodes of cellulitis after surgery, with subjective improvement in limb heaviness and skin pliability.

CONCLUSIONS

The submandibular and upper jugular areas provide an abundant source of lymph nodes for vascularized lymph node transfer with little to no risk of donor site lymphedema. The submandibular group provides an average of 3.2 lymph nodes, and its hilar arterioles are derived from branches of the facial artery in various permutations and the hilar venules drain into the surrounding draining tributaries ultimately into the internal jugular vein. The upper jugular group of nodes provides an average of 4.1 lymph nodes, and the hilar arterioles are derived from the sternocleidomastoid artery, which originate from the STA (70%) or directly from the external carotid artery (30%). The hilar veins drain into surrounding tributaries and ultimately into the internal jugular vein. This knowledge of hilar blood supply is essential to transfer a lymphatic flap with intact microcirculation to the lymphedematous limb.

REFERENCES

1. Aschen SZ, Farias-Eisner G, Cuzzone DA, et al. Lymph Node Transplantation Results in Spontaneous Lymphatic Reconnection and Restoration of Lymphatic Flow. *Plast Reconstr Surg*. 2014;133:301–310.
2. Tobbia D, Semple J, Baker A, et al. Experimental assessment of autologous lymph node transplantation as treatment of postsurgical lymphedema. *Plast Reconstr Surg*. 2009;124:777–786.
3. Saaristo AM, Niemi TS, Viitanen TP, et al. Microvascular breast reconstruction and lymph node transfer for postmastectomy lymphedema patients. *Ann Surg*. 2012;255:468–473.
4. 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;126:93–98.
5. Althubaiti GA, Crosby MA, Chang DW. Vascularized supraclavicular lymph node transfer for lower extremity lymphedema treatment. *Plast Reconstr Surg*. 2013;131:133e–5e.
6. Gharb BB, Rampazzo A, et al. Vascularized lymph node transfer based on the Hilar perforators improves the outcome in upper limb lymphedema. *Ann Plast Surg*. 2011;67:589–593.
7. Becker C, Assouad J, Riquet M, et al. Postmastectomy lymphedema: long-term results following microsurgical lymph node transplantation. *Ann Surg*. 2006;243:313–315.
8. 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.