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PRS GLOBAL OPEN

ORIGINAL ARTICLE
Reconstructive

Establishing a Standard Method for Screening Lymphatic Ultrasound in Lymphedema Patients

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Background: Lymphatic ultrasound (LU) is a valuable tool for treating lymphedema, but no detailed protocol exists. This study aimed to establish a standardized method for screening LU.

Methods: We analyzed LU images from 70 limbs of 35 patients with lower extremity lymphedema (1 man, 34 women; mean age 66.5 y). An 18-MHz linear probe was used, and the D-CUPS (Doppler, crossing, uncollapsible, parallel, superficial fascia) index identified lymphatic vessels. Images were taken at 5 cm (T5) and 10 cm (T10) distal to the saphenofemoral junction and at 5 cm (C5) and 10 cm (C10) distal to the popliteal fossa. Distances between the great saphenous vein (GSV) and lymphatic vessels were measured. Vessel diameters were assessed, and a receiver operating characteristic curve determined the cutoff value for distinguishing normal from dilated lymphatic vessels.

Results: At T5 and T10, lymphatic vessels were identified in 62 limbs (88.6%), with average distances of 17.3 and 15.5 mm lateral to the GSV, respectively. At C5 and C10, vessels were identified in 53 limbs (75.7%), with distances of 12.6 and 13.9 mm medial to the GSV. The receiver operating characteristic curve yielded an area under the curve of 0.83, with a cutoff of 0.25 mm for differentiating normal and dilated vessels.

Conclusions: Lymphatic vessels are generally lateral to the GSV in the thigh and medial to the GSV in the calf. These findings simplify vessel identification, enabling broader use of LU for assessing lymphatic function. *(Plast Reconstr Surg Glob Open 2025;13:e6922; doi: 10.1097/GOX.0000000000006922; Published online 25 June 2025.)*

INTRODUCTION

Lymphedema is a chronic condition caused by impaired lymphatic drainage, often following cancer treatments such as lymph node dissection or radiation.[1] It affects up to 40% of cancer survivors and can cause swelling, pain, and recurrent infections, significantly reducing quality of life. Early detection and management are crucial to preventing progression.[1]

To date, examinations such as lymphoscintigraphy,[2,3] indocyanine green (ICG) lymphangiography,[4–7] and magnetic resonance lymphography[8] have been used to evaluate lymphatic function. However, these techniques often involve drug injection and/or radiation exposure, making them relatively invasive for patients. Additionally, there are limitations in visualizing lymphatic vessels that do not allow drug passage, and even well-functioning lymphatic vessels may not be visualized.[9] Furthermore, lymphoscintigraphy and ICG lymphography are not universally available across all medical institutions, particularly in hospitals in developing countries or rural areas.

Recently, a noninvasive technique called lymphatic ultrasound (LU) has emerged.[10–16] This technique uses relatively high-frequency linear probes to visualize lymphatic vessels and provides detailed information on their function and status. LU is valuable as a preoperative examination for surgical treatments such as lymphaticovenous anastomosis (LVA)[12–17] and can also be used to evaluate lymphatic function and diagnose abnormal lymphatic function.[18,19] Although contrast-enhanced LU[20,21] has been reported, the probe used for this technique is typically around 6–15 MHz, whereas the probe used for noncontrast LU is approximately 18 MHz, offering higher image resolution.

Currently, LU is used in a limited number of medical institutions, and its protocols have not been standardized.[22] If LU becomes a popular screening test for lymphatic function with standardized protocols, it could be

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Received for publication March 7, 2025; accepted May 6, 2025.

DOI: 10.1097/GOX.0000000000006922

Disclosure statements are at the end of this article, following the correspondence information.

implemented in more institutions, benefiting a larger number of patients. This screening tool is likely to benefit patients with limb edema of unknown origin who may have undiagnosed lymphedema. Furthermore, because it provides insight into the degree of lymphatic degeneration, it would also be beneficial for patients who are being considered for surgical treatment of lymphedema.

In this study, we recorded and analyzed the location and properties of lymphatic vessels using lymphatic ultrasonography to identify common sites of lymphatic vessel presence. We hope that the findings of this study will contribute to the development of standardized protocols and encourage the broader use of LU, leading to improved diagnostic accuracy and patient benefits. The primary objective of this study was to establish a standard method for LU and propose a protocol for screening lymphatic ultrasound (SLUS). The purpose of SLUS is to assist in the early detection and evaluation of lymphatic dysfunction in patients presenting with lower extremity edema of uncertain origin, as well as to assess the condition of lymphatic vessels in patients being considered for surgical interventions such as LVA.

Takeaways

Question: This study aimed to establish a standardized method for screening lymphatic ultrasound (LU) to improve the diagnosis and assessment of lymphatic function in lymphedema patients.

Findings: The study analyzed LU images from 70 limbs of 35 lymphedema patients, identifying lymphatic vessels relative to the great saphenous vein at standardized anatomical points. A cutoff value of 0.25 mm was determined for differentiating normal from dilated lymphatic vessels, enhancing diagnostic accuracy.

Meaning: Establishing a standardized screening LU protocol improves lymphatic vessel identification, enabling more accurate and accessible lymphedema diagnostics.

PATIENTS AND METHODS

We analyzed LU images of patients with lower extremity lymphedema who underwent LVA under local anesthesia between January 18 and June 11, 2024. A total of 70 limbs from 35 patients were included: 1 man and 34 women. The mean age was 66.5 years (range: 29–90 y), and the mean duration of lymphedema was 11.5 years (range: 1–60 y). The average body mass index was 21.2 kg/m^2 (range: 17.0–26.2 kg/m^2).

Thirty-one patients had secondary lymphedema, with causative diseases including uterine cancer (16 patients), cervical cancer (9), ovarian cancer (3), and other cancers (3). Four patients developed primary lymphedema. Among patients with secondary lymphedema, 30 (96.8%) underwent lymph node dissection, 23 (74.2%) received chemotherapy, and 7 (22.6%) received radiation therapy.

Lymphoscintigraphy was performed at an outpatient clinic to confirm the diagnosis of lymphedema. For lymphoscintigraphy, 150 MBq of ^{99m}Tc was subcutaneously injected into the first interdigital region on both sides, and images were captured 60 minutes later and classified according to the Maegawa classification.[1] There were 17 type 1 limbs, 9 type 2 limbs, 22 type 3 limbs, 10 type 4 limbs, and 12 type 5 limbs. Additionally, the severity of lymphedema was assessed using the International Society of Lymphology classification: 21 limbs were stage 1, 12 limbs were stage 2a, 31 limbs were stage 2b, and 6 limbs were stage 3.[1] A Noblus ultrasound system with an 18-MHz linear probe (Hitachi Medical Corp., Tokyo, Japan) was used for SLUS.

The previously reported D-CUPS (Doppler, crossing, uncollapsible, parallel, superficial fascia) index was used to identify the lymph vessels.[9] Briefly, the characteristics of lymphatic vessels are defined as follows: Doppler (D): no color Doppler signal; crossing (C): passes through without joining veins; uncollapsible (U): less likely to collapse than veins under probe pressure; parallel (P): multiple lymphatic vessels run parallel without merging; and superficial fascia (S): located just beneath the superficial fascia. The lower limb is divided into several lymphosomes,[23] and our previous study found that the medial side of the lower extremity is a suitable location for SLUS (data not yet published).

In the current study, we examined the medial thigh and lower leg. With the lower limb slightly externally rotated, images were taken at 5 cm (T5 level) and 10 cm (T10 level) distal to the saphenofemoral junction (SFJ). The horizontal distance from the center of the great saphenous vein (GSV) to the center of the lymphatic vessel was measured using the ultrasound device's caliper (Fig. 1). In the calves, measurements were taken at 5 cm (C5 level) and 10 cm (C10 level) distal to the popliteal fossa. Multiple lymphatic vessels within a view were also recorded. The field size used in this study was 2.2 × 3.7 cm. In many cases, when a lymphatic vessel was not initially observed within the same field of view as the GSV, it could be identified by slightly shifting the probe. However, for the purposes of this study, we defined such cases as "no lymphatic vessel observed within the same field of view as the GSV." We investigated the distribution of lymphatic vessels in areas without dermal backflow on lymphoscintigraphy, which indicates no lymphatic function abnormalities, and in areas with dermal backflow.

Lymphatic vessel degeneration is known to occur in limbs.[24,25] At each location, the degree of lymphatic degeneration was determined using the normal, ectasis, contraction, and sclerosis–type classification, and the vertical diameter of the hypoechoic region (lumen of the lymphatic vessel) was measured. To determine the cutoff value between normal and dilated lymph vessels, receiver operating characteristic curves were drawn and analyzed using statistical package for social science. The significance level was set at a value of less than 0.05. This study was approved by the institutional ethics committee (no. R06-10).

RESULTS

Figure 2 shows the distribution of lymphatic vessels at each level.

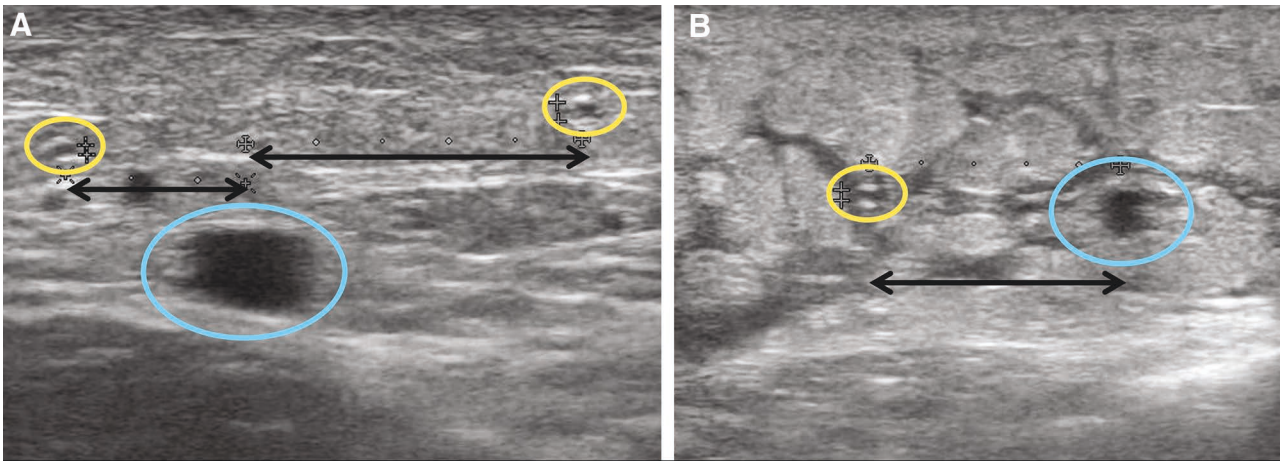

Fig. 1. LU images. Lymphatic vessels (yellow circles) are identified near the GSV (blue circles), and distances from the GSV (black double arrows) and vessel diameters are measured. A, Left thigh: lymphatic vessels (0.7 and 0.4 mm) are located lateral and medial to the GSV, respectively. B, Left calf: a lymphatic vessel (0.4mm) is located medial to the GSV.

At the T5 level, lymphatic vessels were identified in the same field of view as the GSV in 62 limbs (88.6%). Additionally, 17 limbs (24.3%) had 2 lymphatic vessels identified within a single field of view, resulting in a total of 79 lymphatic vessels evaluated. The average distance from the center of the GSV was 17.3 mm lateral (range: 12.0 mm medial to 35.2 mm lateral to the GSV), and 75 (94.9%) lymphatic vessels were located lateral to the GSV.

At the T10 level, lymphatic vessels were identified in the same field of view as the GSV in 62 limbs (88.6%). In addition, 15 limbs (21.4%) had 2 lymphatic vessels identified within a single field of view, resulting in a total of 77 lymphatic vessels evaluated. The average distance from the center of the GSV was 15.5 mm lateral (range: 37.0 mm medial to 37.1 mm lateral to the GSV), and 66 (85.7%) lymphatic vessels were located lateral to the GSV.

At the C5 level, lymphatic vessels were identified in the same field of view as the GSV in 53 limbs (75.7%). Additionally, 10 limbs (14.3%) had 2 lymphatic vessels identified within a single field of view, resulting in a total of 63 lymphatic vessels evaluated. The average distance from the center of the GSV was 12.6 mm medial (range: 37.4 mm medial to 18.7 mm lateral to the GSV), and 53 (84.1%) lymphatic vessels were located medial to the GSV.

At the C10 level, lymphatic vessels were identified in the same field of view as the GSV in 53 limbs (75.7%). Additionally, 10 limbs (14.3%) had 2 lymphatic vessels identified within a single field of view, resulting in a total of 63 lymphatic vessels evaluated. The average distance from the center of the GSV was 13.9 mm medial (range: 36.7 mm medial to 22.0 mm lateral to the GSV), and 58 (92.1%) lymphatic vessels were located medial to the GSV.

Next, we examined the distribution of lymphatic vessels by dividing each level into areas with and without dermal backflow using lymphoscintigraphy (Fig. 3). In the thigh, all lymphatic vessels were located lateral to the GSV in areas without dermal backflow; however, lymphatic vessels were also found on the medial side of the GSV in areas with dermal backflow. In the calves, most lymphatic vessels were located medial to the GSV in areas without dermal backflow; however, more lymphatic vessels were located lateral to the GSV in areas with dermal backflow.

When examining the degree of lymphatic degeneration in 282 lymphatic vessels in the thighs and calves, 73 were categorized as normal and 210 as ectasis. When the receiver operating characteristic curve was drawn, the area under the curve was 0.83, and the significance probability was less than 0.01 (Fig. 4). The cutoff value with the highest prediction accuracy for distinguishing between the normal and ectasis types was 0.25.

DISCUSSION

In the current study, we recorded and analyzed the distance between lymphatic vessels and the GSV observed using LU. Lymphatic vessels were often located lateral to the GSV in the thigh, whereas in cases of abnormal lymphatic vessel function, they were observed medial to the GSV. In calves, lymphatic vessels were frequently located medial to the GSV, and the proportion of lymphatic vessels located lateral to the GSV increased with abnormal lymphatic function. In the present study, we used an 18-MHz linear probe, but lymphatic vessels can also be visualized with a 12-MHz linear probe. Therefore, we believe this technique has the potential to be adopted by a wide range of medical institutions.

In our previous study, the lymphatic vessel identification rates in the thigh and calf using LU were 100% and 96.4%, respectively; however, in the current study, they were 88.6% and 75.5%, respectively.[9] In this study, we aimed to establish an LU protocol that would be easy to use for medical professionals familiar with general lower extremity venous ultrasound to use and to record the positions of lymphatic vessels based on the

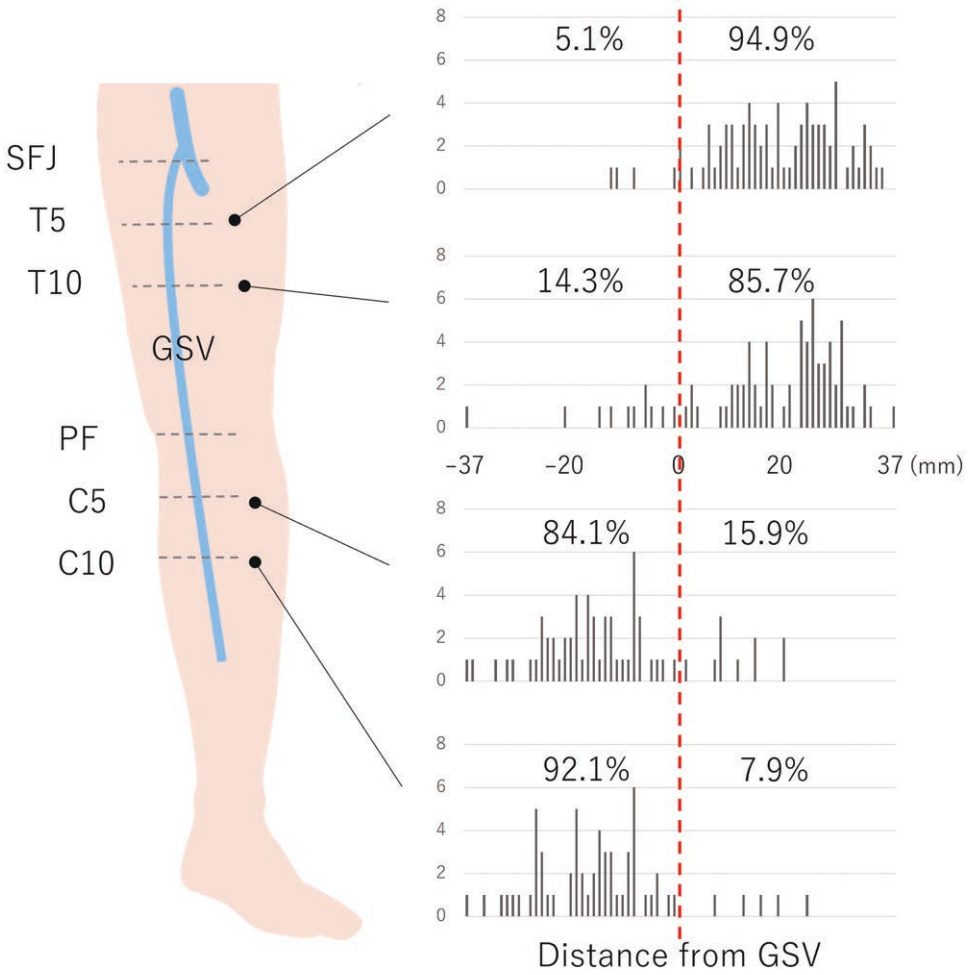

Fig. 2. Distribution of lymphatic vessels. The horizontal axis shows the distance from the GSV, and the vertical axis shows the number of lymphatic vessels. T5 and T10, 5 and 10 cm distal from the SFJ; C5 and C10, 5 and 10 cm distal from the popliteal fossa (PF). Red dotted lines indicate the GSV center.

well-known SFJ and GSV. By focusing on lymphatic vessels visible within the same field of view as the GSV, we simplified the protocol. However, it is important to note that lymphatic vessels can sometimes be found outside the field of view. As examiners become more accustomed to observing lymphatic vessels using ultrasound, they will likely be able to identify lymphatic vessels located farther from the GSV, potentially improving the lymphatic vessel identification rate.

In the current study, examinations were performed in the supine position. Although valvular insufficiency has been reported in patients with lymphedema, particularly in primary cases,[26,27] Mackie et al[28] found that only a small number of patients exhibited valvular insufficiency based on ICG examination. In our previous study on limbs affected by lymphedema, only 20.6% of thighs and 19.7% of calves had dilated lymphatic vessels when the body position was changed from lying to standing.[17] This percentage is even lower in healthy individuals. Given these findings, we concluded that evaluating lymphatic reflux during SLUS is unnecessary and that the supine position is appropriate.

In this study, lymphatic vessels were observed at 5 cm and 10 cm from the SFJ and 5 cm and 10 cm from the popliteal fossa. Based on our clinical experience, these sites were chosen for their ease of identification and suitability for implementation as a screening procedure by medical professionals familiar with general lower extremity venous ultrasound. The height of the popliteal fossa in male young adults has been reported to be 418.9 cm for Japanese and 431.0 cm for Americans, suggesting that the appropriate location may vary depending on race and sex.[29] As knowledge accumulates, it will be possible to identify more suitable sites for SLUS, which is a topic for future research.

Based on these results, the authors propose the following protocol for SLUS:

1. Place the patient in a supine position with the leg to be examined externally rotated.
2. Place the ultrasound probe on the groin to identify the SFJ.
3. From there, scan toward the distal side of the GSV and observe the area lateral to the GSV under the superficial fascia.

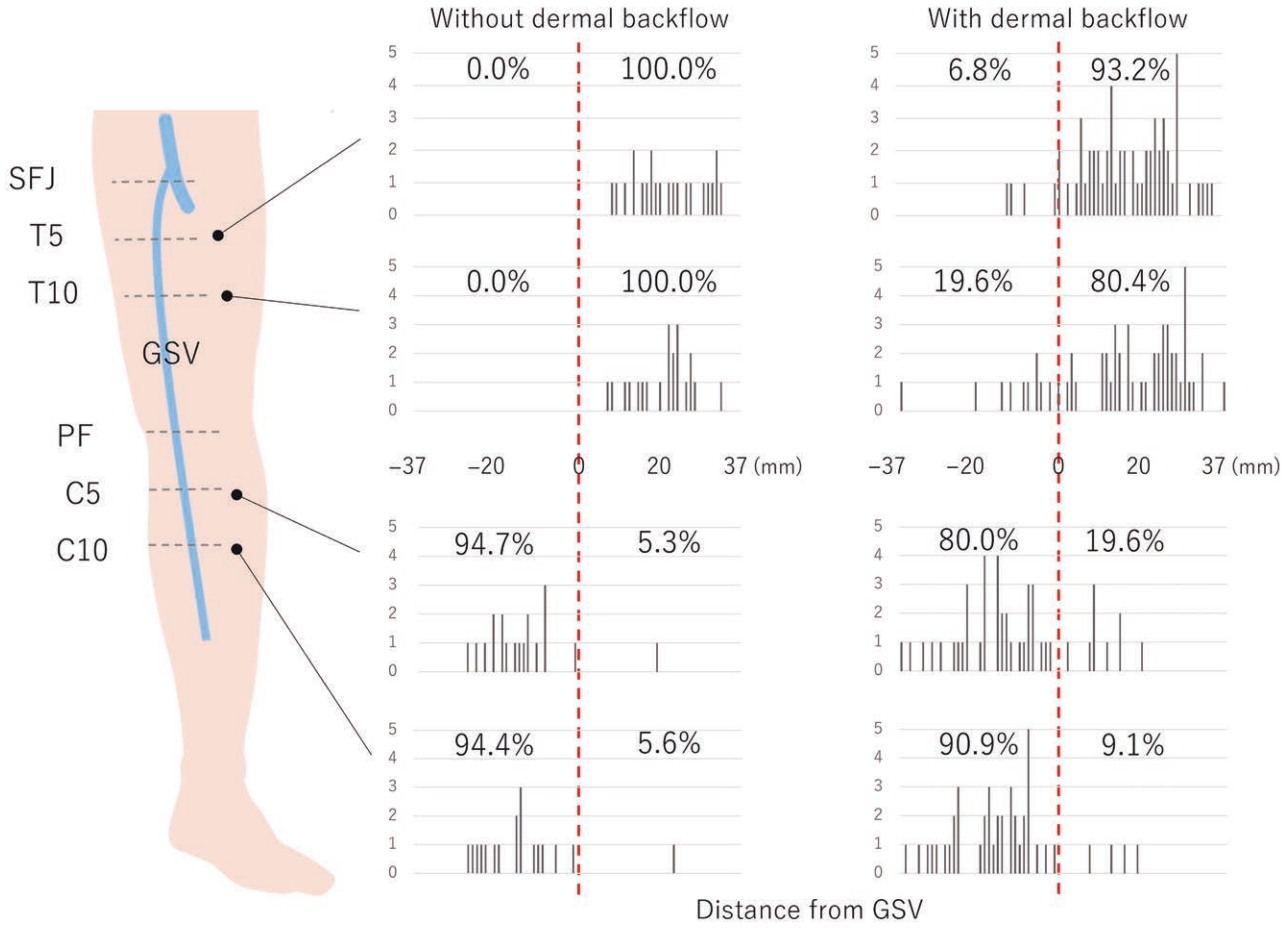

Fig. 3. Lymphatic vessel distribution by dermal backflow on lymphoscintigraphy. The horizontal axis shows the distance from the GSV, and the vertical axis shows the number of lymphatic vessels. T5 and T10, 5 and 10 cm distal from the SFJ; C5 and C10, 5 and 10 cm distal from the popliteal fossa (PF). Red dotted lines indicate the GSV center.

4. Normal lymph vessels appear hyperechoic, small, and equally marked (=). Lymphatic accumulation in lymphatic vessels resembles veins and appears as a hypoechoic round. Once a structure that appears to be a lymphatic vessel is identified, move the probe distally and proximally; if the structure runs horizontally beneath the superficial fascia, it may be a lymphatic vessel (S in D-CUPS). If no lymphatic vessels are found on the lateral side, also observe the medial side of the GSV.
5. Follow the vessel proximally and confirm that it does not join a nearby vein (C in D-CUPS).
6. Confirm that no color appears in the Doppler mode, preferably in high-definition mode, such as microvascular imaging (D in D-CUPS).
7. Measure the vertical caliber of the lymphatic vessels. If it is thinner than 0.25 mm, it is considered normal. If it is thicker than 0.25 mm, it is considered dilated, and lymph vessel dysfunction is diagnosed. Additionally, if there is dilation, attempt to compress it with a probe and confirm that it is less likely to collapse than a vein (U in D-CUPS).
8. Next, identify the GSV at the level of the popliteal crease and evaluate the lymphatic vessels under the superficial fascia medial to the GSV. If no lymph vessels are found medial to the GSV, observe the lateral side.

If SLUS is performed using the protocol described earlier, it can be completed in approximately 3 minutes for 1 leg and 6 minutes for both legs. By incorporating SLUS into lower extremity venous ultrasound examinations, which are already performed to investigate the cause of lower extremity edema, it is more likely that an appropriate diagnostic and treatment plan can be provided. As LU becomes widely adopted in various medical institutions, protocols should be further refined and improved.

A limitation of this study is that, because our primary aim was to standardize screening points for LU, the ultrasound examinations were not necessarily performed at sites optimal for LVA, and the lymphatic vessels observed in this study were not surgically confirmed. However, we have accumulated nearly a decade of experience in directly visualizing lymphatic vessels identified by ultrasound during surgery, and we have analyzed how different types of lymphatic vessels appear on ultrasound. The results of these investigations have been reported in several previous publications. Based on this body of work, we believe that the accuracy of LU has already been well demonstrated.

In conclusion, lymphatic vessels in the thigh are often located lateral to the GSV, and in cases of abnormal

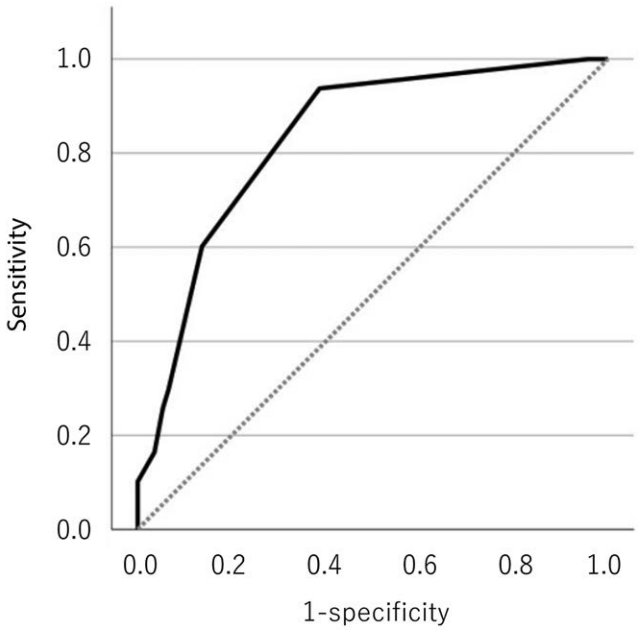

Fig. 4. Receiver operating characteristic curve. The cutoff between normal and dilated lymphatic vessels was 0.25 mm. The area under the curve was 0.83 ($P < 0.01$).

lymphatic function, they can also be observed medial to the GSV. In calves, lymphatic vessels are typically located medial to the GSV, and the proportion of lymphatic vessels located lateral to the GSV increases when there is abnormal lymphatic function. The cutoff value to distinguish between normal and ectasis types of lymphatic vessels was determined to be 0.25 mm. These results could enable physicians and ultrasound technicians to easily identify lymph vessels, potentially leading to a more widespread examination of lymphatic function.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

ETHICAL APPROVAL

This study was approved by the institutional ethics committee (No. R06-10).

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