Original Article

Clinical application of magnetic resonance lymphangiography in the vascularized omental lymph nodes transfer with or without lymphaticovenous anastomosis for cancer-related lower extremity lymphedema

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Background: The recent increase in the number of patients with lower extremities lymphedema and the development of microsurgery techniques have led to a rise in lymphedema treatment. Vascularized omental lymph node transfer (VOLT), an emerging treatment modality for extremity lymphedema, has shown its unique advantages in reconstructing lymphatic circulation and absorbing exudated lymphatic fluid. Patients who underwent radical tumor resection with/without radiation therapy treatment often present with impairment or degeneration of the inguinal lymph nodes. For such cases, VOLT could provide adequate lymph nodes and tissue to absorb edema fluid in these areas. Therefore, we analyzed the operative outcomes of VOLT under the guidance of magnetic resonance lymphangiography (MRL) in this study, as this individualized and precise surgical procedure could benefit patients and improve their quality of life.

Methods: From November 2021 to September 2022, a total of 14 patients' 19 legs with extremity lymphedema underwent a VOLT with or without lymphaticovenous anastomosis (LVA). Outcomes, including circumference reduction rates, preoperative and postoperative MRL results, and other complications, were analyzed.

Results: The mean follow-up period was 8.86±1.41 months (range, 7–11 months). The mean circumference reduction rates {circumference reduction rate (%) = [1 − (postoperative affected limb − healthy limb)/(preoperative affected limb − healthy limb)] × 100%} of different planes (i.e., ankle, 10 cm above the knee, 10 cm below the knee, 10 cm above the ankle, and 20 cm above the knee) were 15.64%±40.08%, 11.79%±30.69%, 20.25%±24.94%, 7.73%±30.05%, −1.517%±16.75%. Notably, one patient had multi-drug–resistant gram-negative infections, which resulted in the loss of three flaps. The postoperative MRL showed improved lymphatic drainage and lower extremity volume in the remaining 13 cases.

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Conclusions: The precision evaluation of inguinal lymph nodes and lower extremities lymphatic system through MRL using VOLT can provide surgeons with a comprehensive understanding and reliable evidence for the treatment of cancer-related lower extremity lymphedema.

Keywords: Lymphedema; super-microsurgery; lymphatic venous anastomosis; magnetic resonance lymphangiography (MRL); vascularized lymph node flap transfer

Submitted Dec 28, 2022. Accepted for publication Jul 31, 2023. Published online Aug 08, 2023.
doi: 10.21037/qims-22-1443
View this article at: https://dx.doi.org/10.21037/qims-22-1443

Introduction

Although radical gynecological oncological surgery is recommended to clear tumors and prevent their recurrence, extensive regional lymph node dissection, scar hyperplasia, radiotherapy, and other factors can cause extremity lymphedema. It has been reported that surgery-related extremity lymphedema incidence is as high as 25% (1,2), which could seriously affect human physical and mental health and quality of life. In recent years, intraperitoneal lymph node flap represented by omental lymph node flap transfer has been used to reconstruct the lower extremity lymphatic system. Even though its applicability has been popularized because of its rich blood supply and abundant lymphatic tissue, concealed incision, low complication rate, and predictable surgical outcome, its blinded surgical approach may cause injury to the healthy lymph nodes and vessels, especially in the inguinal region. With the advent of magnetic resonance lymphangiography (MRL), surgeons can now acquire more intuitionistic and precise information about the lower extremities' lymphatic system which helps for a better surgical planning and execution.

MRL with subcutaneous injection of gadolinium has been proposed as a safe method for preoperative assessment of lymphatic channels due to its high spatial resolution. The three dimensional (3D) imaging provided by MRL enables the visualization of small lymphatic channels beyond the capabilities of traditional lymphoscintigraphy (3,4). Several studies have demonstrated that MRL is capable of identifying lymphatic vessels that are not visible with indocyanine green (ICG) lymphography, particularly those located deep beneath the skin (>2 cm deep), while also providing detailed information on lymphatic channel number, depth, trajectory, and regions of dermal backflow. MRL is a valuable technique for preoperative mapping of functional lymphatics and adjacent veins in limbs, assessing tissues in the affected limb, and improving patient selection for optimal surgical choice for lymphedema (5-7). This study aimed to formulate a precise and individualized treatment plan in conjunction with a better incision design by applying MRL for the reconstruction and repairment of lower extremity lymphedema with the aid of vascularized omental lymph node transfer (VOLT).

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics board of Xiangya Hospital, Central South University and informed consent was taken from all the patients. From November 2021 to September 2022, 14 patients with cancer-related lower extremity lymphedema underwent VOLT with or without lymphaticovenous anastomosis (LVA) using MRL for preoperative evaluation. An AIR Technology™ Anterior Array Coli was placed over the most edematous areas, while the other anterior array coli covered the rest of the extremities. All patients underwent MRL under a magnetic resonance scanner, as previously reported (8,9). The patients were initially plain-scanned in a prone position. A mixture of 1 mL of lidocaine with 10 mL of gadolinium contrast agent was then prepared. All patients received an intra-dermal injection of the mixture in their double-toe pads, which was swiftly massaged to facilitate the proximal diffusion of the contrast agent. The specific sequences are shown in *Table 1*. All the patients enrolled in this article were measured leg circumference and calculate circumference reduction rate during the follow-up period. All statistical analyses were performed using SPSS 26.0 software (SPSS, Chicago, IL, USA). Data were expressed as mean ± standard error of mean, and a P value <0.05 was considered statistically significant.

Table 1 Detailed instructions for transpedal MRL

Sequence name	Sequence details		
	1	2	3
MRI sequence	3D-T2WI	T2WI	3D-T1WI
Orientation	COR	AXI	COR
Field-of-view (mm^2)	360×468	400×280	360×468
Slice thickness (mm)	3	6	1.4
TR (ms)	2400	5129	7.3
TE (ms)	90	85	1.1/(2.2/233.6)
Bandwidth	62.5	83.3	200
Flip angle	–	111	15
NEX	2	1	1
Scan time (min: sec)	2:25	2:49	1:35

MRL, magnetic resonance lymphangiography; MRI, magnetic resonance imaging; COR, coronal; AXI, axial; T2WI, T2 weighted image; T1WI, T1 weighted image; TE, echo delay time; TR, repetition time; NEX, number of excitations.

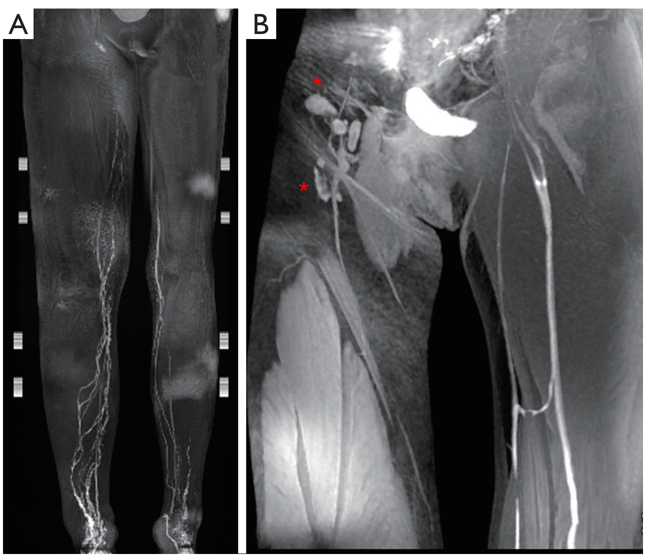

Figure 1 MRL image of normal lymphatic vessels and lymph nodes. (A) Normal lymphatic vessels are continuous, slender bead-like vessel. (B) "*" marks the normal deep inguinal lymph nodes and superficial inguinal lymph nodes. MRL, magnetic resonance lymphangiography.

Surgical operation

The incision design was based on the result of preoperative MRL combined with intraoperative ICG fluorescence. The choice of surgical approach is not only determined by the patients' stage and appearance, but we will also consider performing VOLT in patients with non-significant edema if their lymph nodes and lymphatic vessels suggest poor function compared to normal images (*Figures 1,2*). We determined the anastomosing lymphatic vessels and designed the transverse incision to avoid injuring the healthy lymphatic vessels and lymph nodes by drawing the surgical incision in the recipient area of the skin flap. Then methylene blue was subcutaneously injected at 5–6 cm distal to the end of the incision. After incision, the dissociated blue-stained lymphatic vessels and the diameter-matched veins were selected for end-to-end anastomosis. It is worth noting that as long as the MRL and ICG fluorescence results showed the presence of healthy lymphatic vessels, LVA would be performed on these vessels; however, if the patient did not have sufficient healthy lymphatic vessels to undergo LVA alone and present with impaired inguinal lymph node function, we would resort to performing VOLT (*Figure 3A-3C*). LVA was performed under the microscope (Zeiss Kinevo 900, Oberjoken, Germany) using 11-0 Ethilon sutures (Ethicon, LLC, USA) (*Figure 3D*). After LVA, microsurgeons prepared the recipient site for the omental lymph node flap. Typically, the ankle region above the medial malleolus was being selected, with an S-shaped incision drawn before proceeding with the surgery. Another S-shaped incision was made just below the groin, preserving the femoral or superficial epigastric artery and its accompanying vein. Meanwhile the greater omentum was explored using laparoscopy by the general surgeon. The pedicles of the left and right gastroepiploic arteries were cut off with an ultrasonic scalpel, and Hammlock clips were used to mark the vascular pedicle. The vascularized omentum was then delivered to the lower limb, and was divided into several omental lymph node flaps of appropriate sizes at the recipient site under the microscope (Zeiss Kinevo 900, Oberjoken, Germany). The smaller flap close to the vascular pedicle was designed as a flow-through perforator flap transplanted to the distal recipient site, while the larger one was transplanted into the proximal site (*Figures 4-7*). The number of flaps used depended on the status of the lymphoedema. For the limb without a healthy inguinal lymph node, two flaps instead of one flap would be transplanted on the calf part. The vascular anastomoses were performed using 10-0 Prolene sutures (Ethicon, LLC, USA). Surgical drain was inserted after adequate hemostasis, and the incision of the first stage operation was closed directly. Clinical photos were taken during the operations

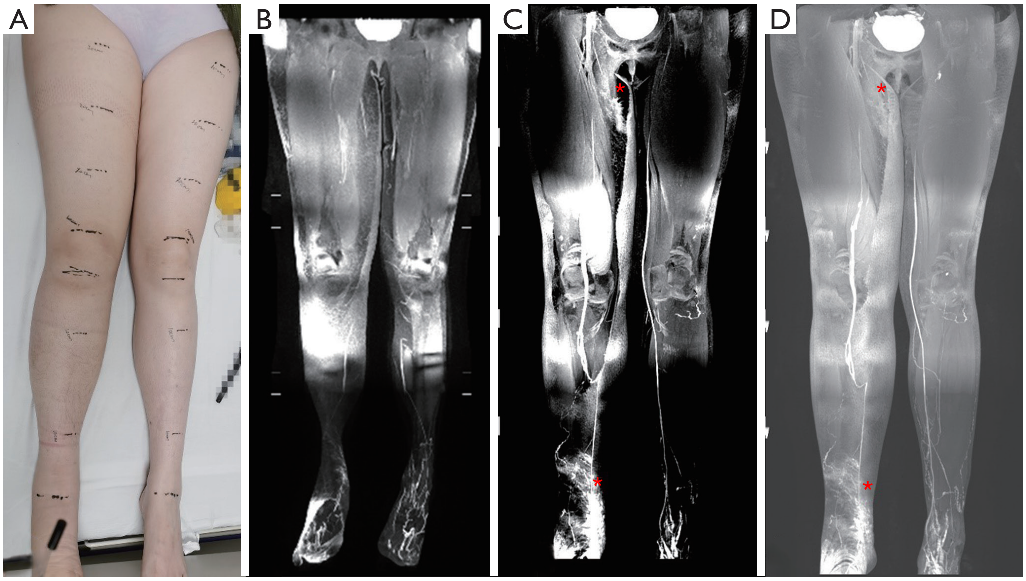

Figure 2 Preoperative photos of patients with insignificant edema and preoperative and postoperative MRL results. (A) Pre-operative photo of the patient and no significant difference in the size of two legs. (B) Pre-operative MRL result. There are no normal lymph nodes in the right leg and only few normal lymphatic vessels so we determined to perform VOLT combined LVA. (C,D) Post-operative MRL result. "*" marks the replanted vascularized omental lymph node flap. This image is published with the patient's consent. MRL, magnetic resonance lymphangiography; VOLT, vascularized omental lymph node transfer; LVA, lymphaticovenous anastomosis.

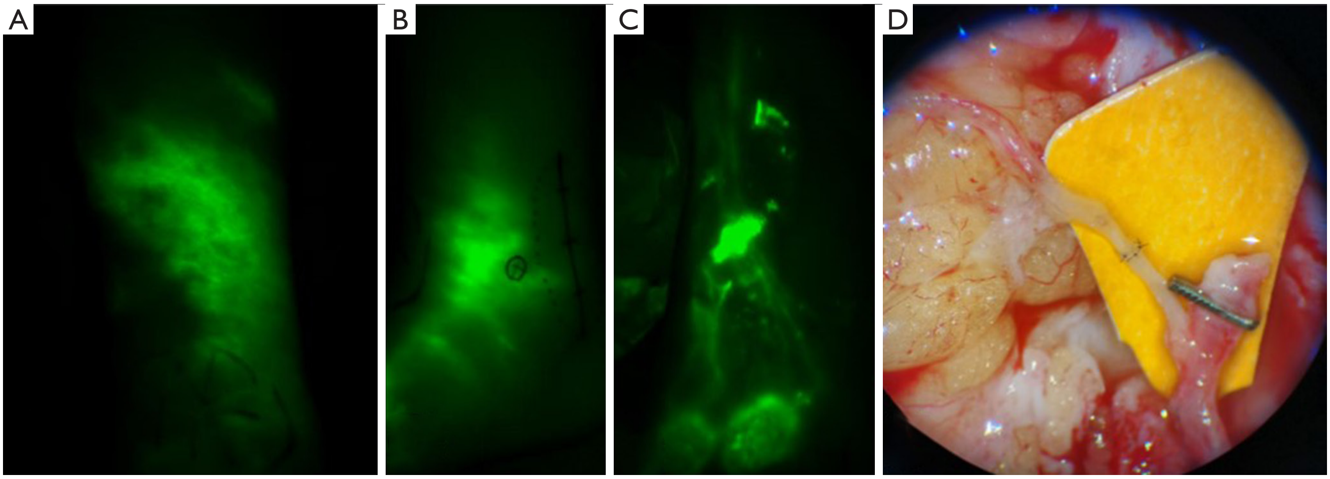

Figure 3 Preoperative ICG fluorescence result and the LVA photo under the microscope. (A,B) The result showed the lymphatic function was poor and we designed the incision on the place without healthy lymphatic vessels. (C,D) If the lower limb showed healthy lymphatic vessels, we performed LVA under the microscope. ICG, indocyanine green; LVA, lymphaticovenous anastomosis.

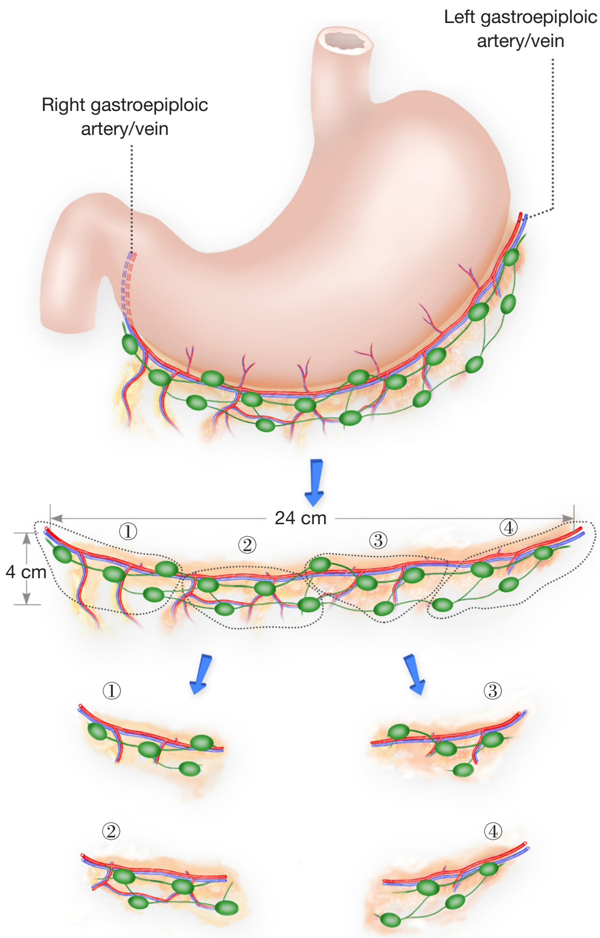

Figure 4 Schematic representation of vascularized omentum acquisition. If a recipient area requires a relatively high number of lymphatic tissues, the left and right gastroepiploic arteries are cut off as the donor pedicle. We performed electrocoagulation on all branches to prevent bleeding.

and after the surgery, all patients underwent re-examination using MRL (*Figure 8*).

Statistics

Statistical analysis was performed using SPSS software (ver.26.0; SPSS, Chicago, IL, USA). Use the ROUT test to reject outliers and all the results are expressed as means ± standard error of mean.

Results

A total of 14 female patients with 19 extremities underwent VOLT. The mean patients' age was 53.64±10.27 years (range, 33–64 years), the mean BMI was 26.99±4.11 kg/m^2 (range, 18.7–32.5 kg/m^2), and the mean follow-up time was 8.86±1.41 months (range, 7–11 months). Nine patients were diagnosed with cervical cancer, 4 with endometrial cancer, and 2 with ovarian cancer. The average duration of lymphedema symptoms was 5.86±3.79 years (range, 0.25–1 years). Ten patients were classified as stage II and 4 with stage III according to International Society of Lymphology (ISL). Three flaps of one patient were lost due to multi-drug-resistant infection while all the other 32 flaps survived. All patients except one underwent LVA, and the mean number of anastomoses was 1.53±1.90 (range, 0–3). The recipient arteries selected include the posterior tibial artery, superficial epigastric artery, adductors muscles perforator artery, medial circumflex femoral artery, and medial sural artery according to site and vessel condition seen during the surgery. The mean total operating time was 10.10±1.94 hours (range, 6.2–12.3 hours). Two patients developed postoperative recipient area effusion, and during the follow-up period, two patients were affected with lymphangitis. During the follow-up period, the reduction of the limb circumference was measured in term of percentage compared to pre-operative findings. The patients with post-operative effusion were placed negative pressure suction device after the second surgical debridement. When the effusion was completely eliminated, the negative pressure drainage device was removed and the patient followed complex decongestive therapy for 3 weeks. The measurement was performed by the same operating surgeon with more than 3 years of clinical experience. Measurements were made in 5 locations which included the ankle, 10 cm above the ankle, 10 cm below the inferior pole of the patella, 10 cm above the superior pole of the patella, and 20 cm above the superior pole of the patella. According to the above order, the mean circumference reduction rates were 15.64%±40.08%, 11.79%±30.69%, 20.25%±24.94%, 7.73%±30.05%, −1.517%±16.75%, respectively. The patients' information is shown in *Tables 2-4*.

Discussion

Nowadays, personalized and precision treatment is the major trend in clinical medicine. Technical advances in magnetic resonance imaging have made it possible to develop a non-invasive visualization method of the lymphatic system, which was not possible in the past (10). With the advent of MRL technology, microsurgeons could

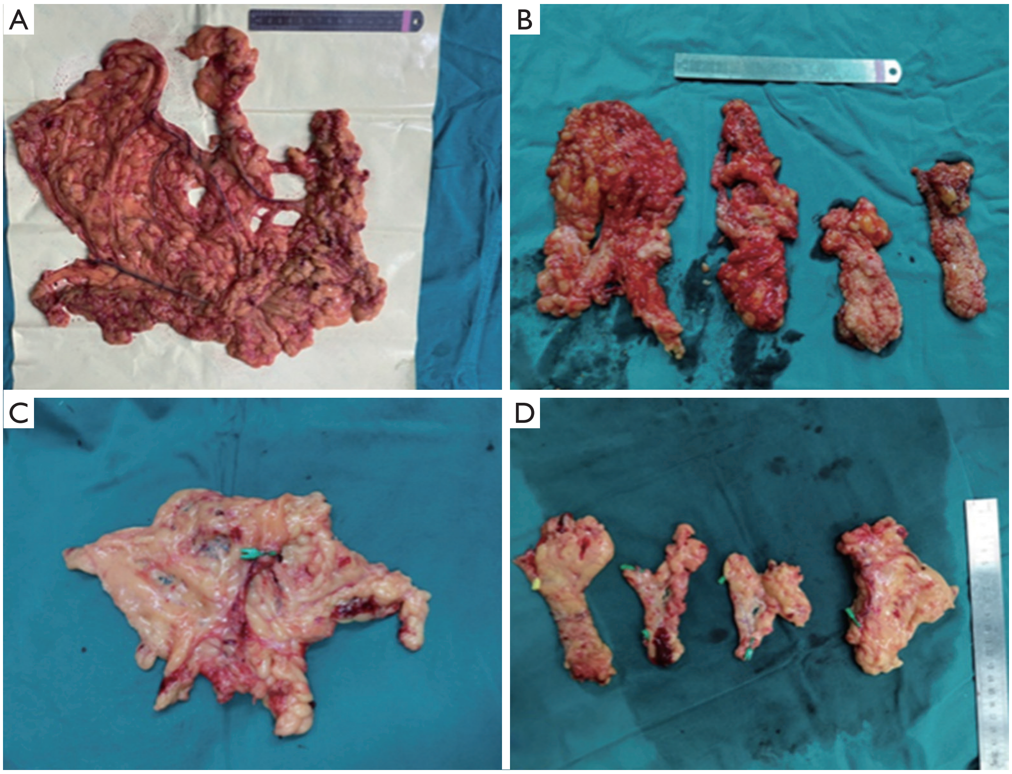

Figure 5 Schematic representation of vascularized omentum division. The vessel pedicles were differentiated under the microscope by microsurgeons and divided into required flaps as needed. (A) Complete omental tissue before division. (B-D) The vascularized omental lymph nodes flap was divided into several omental lymph node flaps of appropriate sizes at the recipient site under the microscope.

provide individualized treatment and surgical management according to the varying conditions of patients. In this study, we combined the MRL technique and super-microsurgery technological capability. MRL, a noninvasive indirect lymphography, allows for comprehensive examination as the contrast agent used has strong absorption, better histocompatibility, and ease of metabolism (11).

The traditional imaging examinations for lymphedema involve ICG fluorescence and lymphoscintigraphy. ICG fluorescence, limited by the excitation light source, its investigation depth is unable to reach the deep inguinal lymph node group so the surgeons can't evaluate the function of lymph nodes directly. Although lymphoscintigraphy can reflect the lymph nodes function to a certain extent, the results will miss the condition and location of lymphatic vessels. MRL involves the subcutaneous injection of a contrast agent, which is taken up by macrophages and retained in the lymph nodes before being absorbed by lymphatic drainage to reveal the lymphatic system. It has become the "gold standard" of diagnosis and guidance for formulating clinical treatment schemes as it has less trauma, less pain, short consumption time, clear images, and other benefits. The assessment of lymphedema limb is evaluated in terms of both the severity of edema and the condition of lymphatic tissue. Contrasted with other lymphangiography methods, MRL can reflect the fluid change of preoperative and postoperative limbs more objectively and accurately. All these methods emphasize the importance of MRL in guiding surgery design. In addition, in our another study, data analysis was performed momentarily on 51 patients with lymphedema underwent MRL (including 11 patients enrolled in this study), MRI stage was performed for the severity of lymphedema patients (ISL stage 0, I, II, III), and imaging features such as cellular, dermal thickening, muscle abnormalities, and distal lymphangiectasia were evaluated. The correlation between imaging results and clinical stage, distal lymphangiectasia and surgical method were evaluated

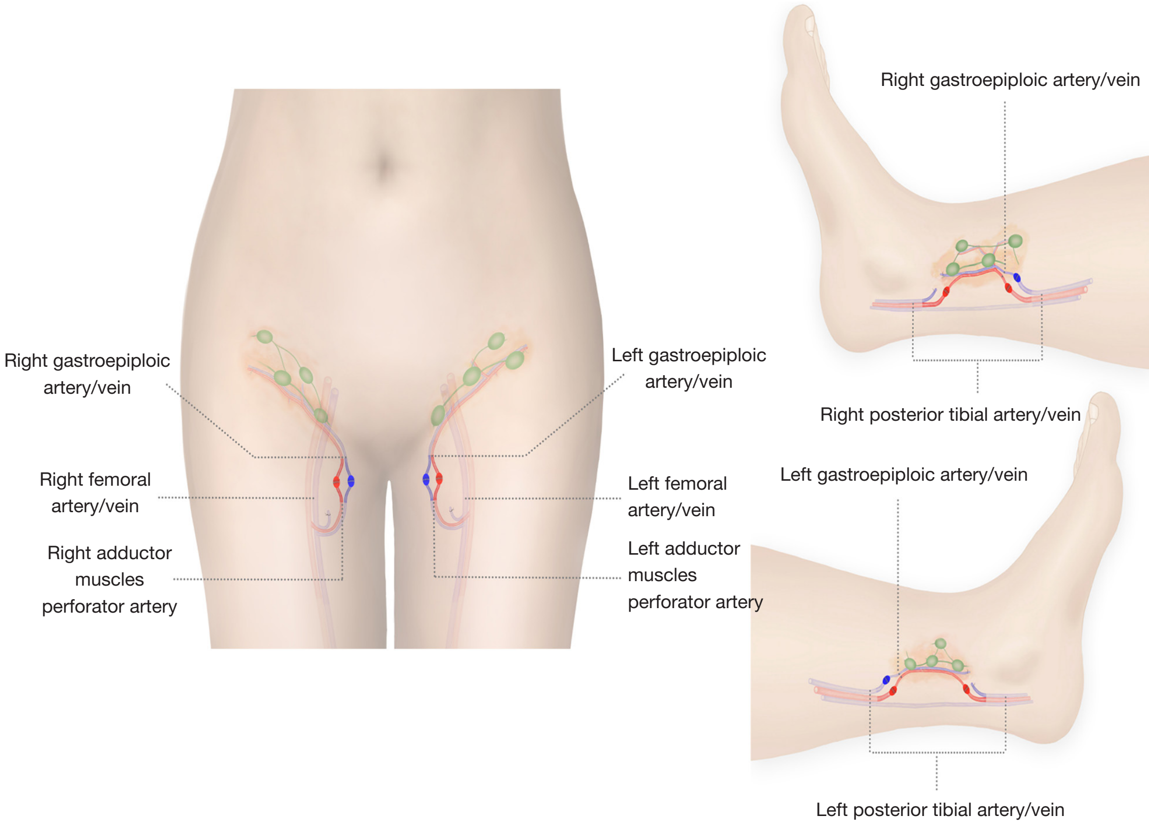

Figure 6 Schematic representation of VOLT operation design. The vascularized omentum was separated into several suitable omental lymph node flaps at the recipient site. Larger ones were transferred to the upper recipient (i.e., thigh), and smaller ones closed to the vascular pedicle were transferred to the lower recipient site. VOLT, vascularized omental lymph node transfer.

in 24 patients who underwent LVA. The results indicated that the clinical stage of lymphedema was positively correlated with the MRI stage, MRI features such as distal lymphatic vessel dilatation and muscle abnormality were positively correlated with the ISL stage of lymphedema. Therefore, based on these preliminary results, we believe that MRL can provide important diagnostic information for the treatment of patients with lower limb lymphedema.

Based on the preoperative MRL and intra-operative ICG fluorescence result, we decided to perform LVA alone for the patients with healthy lymphatic vessels and nodes, for LVA should be regarded as the primary treatment for lymphedema, while vascularized lymph nodes transfer and liposuction may be considered as additional procedures, thus establishing this as the standard approach for lymphedema (12). However in our study, none of the enrolled patients had sufficient healthy lymphatic vessels, all of objects combined function impairment of inguinal lymph nodes (13,14). As for those with loss or hypofunction of lymph nodes or with severe lymphatic system injury, basing on the combined assessment result of MRL, ISL stage, and degree of clinical subcutaneous adipose hyperplasia and tissue fibrosis, we chose VOLT to improve their local tissue microenvironment and to reconstruct the collateral circulation of the peripheral lymphatic system which in turn could improve the edema and reduce the frequency of local infections.

In addition, to improve the patient's overall condition, we employed the precision mapping of MRL as this could guide surgeons to avoid damaging to the normal healthy lymphatic tissue. Moreover, since the proximal recipient site of the lower limb was chosen at the inguinal region, performing VOLT at this location might cause injury to inguinal lymph node function; therefore, MRL results can also help the surgeons to avoid causing iatrogenic injury. Superficial lymph nodes flap transfer such as submandibular

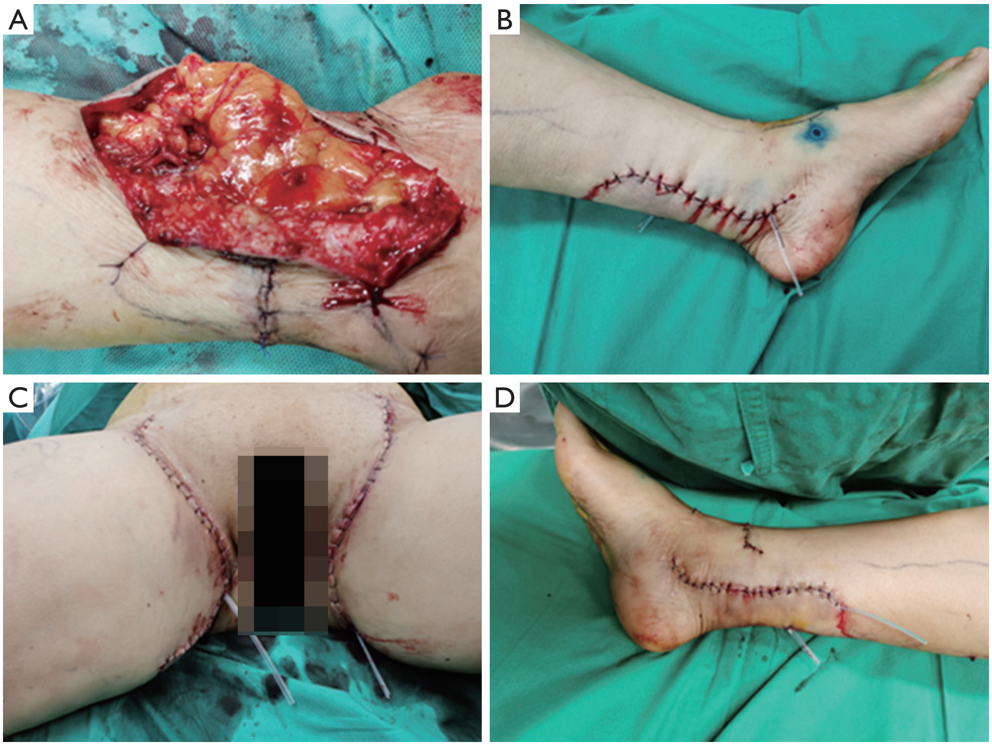

Figure 7 A four-segment VOLT intra-operative and immediate post-operative pictures. (A) the medial calf underwent flow-through omentum lymph node flap transfer, and the recipient artery chosen was the posterior tibial artery. (B-D) Following surgery, incisions were closed with the primary suture without skin grafting. This image is published with the patient's consent. VOLT, vascularized omental lymph node transfer.

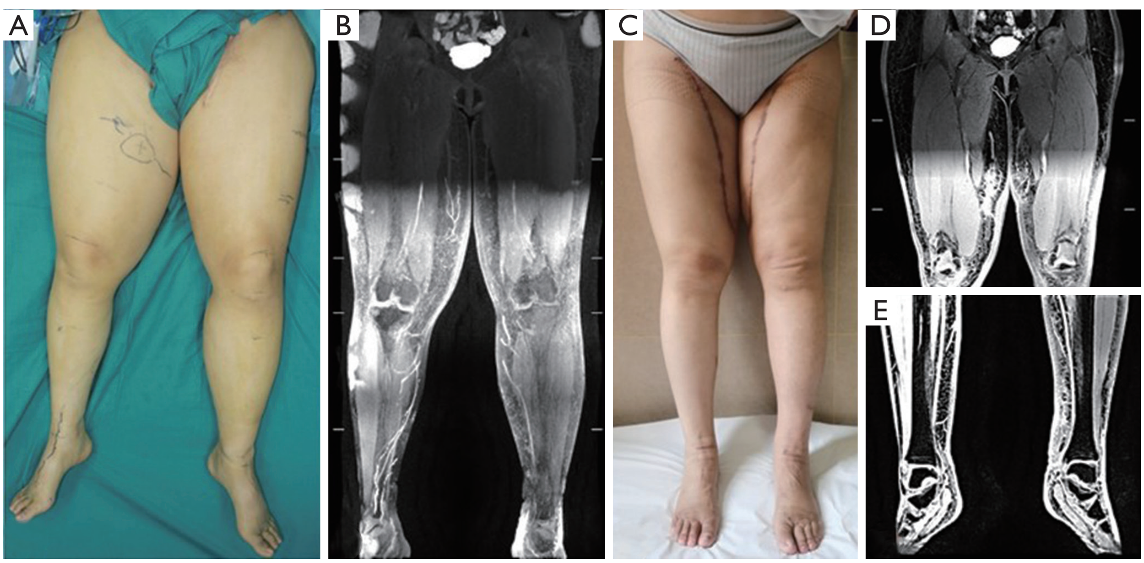

Figure 8 Pre- and post-operative gross anterior MRL images of one patient. (A,B) Pre-operative gross and anterior MRL images suggested right calf lymphatic vessels morphology and function were normal, but the left calf showed no well-development lymphatic vessels. Both legs appeared to have no inguinal lymph nodes and medial femoral lymph nodes. (C-E) A 7-month post-operative gross and anterior MRL image showed the leg circumference was reduced, and the transferred vascularized omental lymph nodes survived. This image is published with the patient's consent. MRL, magnetic resonance lymphangiography.

Table 2 The basic information of the patients

Patients	Age (years)	BMI (kg/m^2)	Cancer diagnosis	Lymphedema lasting time (years)	Affected limb	ISL stage	Follow-up (months)	Complication
1	44	30.8	Cervical cancer	10	Right	II	11	None
2	64	28.4	Endometrial cancer	Left: 1; right: 6	Both	II	10	Recipient area effusion
3	43	29.4	Cervical cancer	7	Both	II	10	None
4	43	23	Ovarian cancer	11	Both	II	10	None
5	64	23.8	Cervical cancer	7	Left	III	10	None
6	55	28.2	Cervical cancer	4	Both	II	9	None
7	63	18.7	Ovarian cancer	0.8	Right	II	9	None
8	64	32.5	Endometrial cancer	11	Left	III	8	None
9	56	31.3	Endometrial cancer	5	Right	III	7	None
10	62	30.8	Cervical cancer	5	Both	III	7	Multi-drug-resistant infection
11	56	22.9	Cervical cancer	4	Right	II	7	Recipient area effusion
12	33	26.5	Cervical cancer	12	Right	II	9	None
13	60	22.8	Cervical cancer	0.25	Right	II	10	None
14	44	28.8	Cervical cancer	8	Left	II	7	None
Mean ± SEM	53.64±10.27	26.99±4.11	N/A	5.86±3.79	N/A	N/A	8.86±1.41	N/A

BMI, body mass index; ISL, International Society of Lymphology; SEM, standard error of mean; N/A, not applicable.

lymph nodes have been frequently employed as donor sites because of their clear architecture, simple harvesting, and long-lasting effect. However, the donor sites may develop lymphedema and lymphatic fistula. Besides, peripheral nerves can be easily damaged during surgery, and the patient's postoperative beauty may be affected by the relatively large incision and prominent postoperative scar. In contrast, laparoscopic techniques can be used to sample omental lymph nodes with a hidden incision, slight bleeding, and other advantages, such as obtaining enough lymphoid tissues in one donor site, avoiding postoperative lymphedema, reducing limb edema more quickly due to the excellent adsorption capacity. What's more, benefiting from its anatomical structure, the greater omentum has more lymph nodes than superficial flap and can be applied to treat multiple limb lymphedema, for these reasons many studies have reported that omental lymph node transfer is superior to superficial lymph node transfer in limb detumescence through the long-term follow-up result (15-19).

However, due to individual patient differences and other factors, such as technical conditions, there are some limitations in its clinical application. For instance, in patients with severe edema and fibrosis, using a 1 mL syringe to perform subcutaneous injection may lead to challenges such as high subcutaneous pressure that makes injecting the contrast agent difficult and may result into an overflow of the contrast agent after its administration. Similarly, during the process of mixing the agent with the local anesthetic, the high pressure generated may bring pain and fear to patients during the administration procedure. Besides, MRL guidance cannot be directly utilized in the operation that needs another ICG fluorescence to determine the result, as its accuracy and sensitivity are not as good as when used singly with MRL. Moreover, its clarity in patients with severe edema is poor, which sometimes misguides the operation and clinical judgment of surgeons. For patients with metal implants placed in their previous operation, the image quality will be affected because of the influence of such materials, and the long duration of the MR examination process will lead to metal thermogenic reactions. All these factors mentioned above may cause the failure of radiography. Finally, during the

Table 3 The surgery details of the patients

Patients	Flap numbers	Flaps survival	LVA numbers	Recipient arteries	Episode numbers of lymphangitis		Total surgery time (hours)
					Pre-operative follow-up	Post-operative follow-up	
1	2	2	0	PTA, AMPA	3	0	7.5
2	3	3	Left: 1; right: 1	SEA, AMPA	7	0	12.3
3	3	3	Left: 2; right: 1	PTA, AMPA	Countless	1	13
4	4	4	Left: 0; right: 1	PTA, AMPA	Countless	0	9.5
5	3	3	2	MCFA, MSA, PTA	Countless	0	8.5
6	3	3	Left: 3; right: 1	PTA, AMPA	0	0	12.3
7	1	1	2	PTA	3	0	6.2
8	2	2	2	PTA, AMPA	8	0	8.6
9	2	2	2	PTA, AMPA	11	0	10
10	4	1	Left: 2; right: 2	PTA, SEA	3	1	11
11	2	2	2	PTA, AMPA	0	0	10
12	2	2	2	PTA, AMPA	2	0	11.5
13	2	2	3	PTA, AMPA	3	0	11
14	2	2	0	PTA, AMPA	1	0	10
Mean ± SEM	2.50±0.85	2.29±0.83	1.53±1.90	N/A	N/A	0.14±0.36	10.10±1.94

LVA, lymphaticovenous anastomosis; PTA, posterior tibial artery; AMPA, adductors muscles perforator artery; SEA, superficial epigastric artery; MCFA, medial circumflex femoral artery; MSA, medial sural artery; SEM, standard error of mean; N/A, not applicable.

follow-up period, taking MRL is difficult for the patients due to the high cost and insufficient technical know-how of local hospitals; however, comparing the MRL results, the figures of measuring tape or body composition measuring instrument directly reflect the changes of the limbs, which are easier to understand for patients with low literacy.

Regarding the operation process in this study, we performed a one-stage 1–4 segments VOLT for the treatment of lower extremities lymphedema and designed an S-shaped incision to achieve an esthetic and covert postoperative appearance. Because the acquisition of the omentum is obtained by laparoscopy, postoperative adhesion of abdominal contents may occur after abdominal closure, and the survival and growth of residual omentum are uncertain after cutting off the vessel pedicle. Therefore, patients have only one operation opportunity, and a one-stage operation can not only treat lower extremities lymphedema but also reduce the pain and economic burden of multiple operations.

Despite advantages of one-stage operation, for patients with multiple sites of lymphedema, the multi-segment VOLT can be difficult, due to the long duration of surgery, high physical and technical demand for the skilled operators, and the difficulties of postoperative care. In addition, patients with combined perineum edema, in which the proximal incision is close to the perineum and anus, are unavoidably facing with the possibility of getting infected from their excretions. In this study, one of the patients was affected by postoperative infection leading to the loss of three flaps; therefore, extra caution should be exercised when surgeons design the incision pattern.

At present, there is still no consensus regarding the surgical incision design. The mainstream view is that transplanting the lymph node flap to the distal site can achieve a better postoperative outcome than the proximal choice, i.e., the edema fluid would move to the distal limb due to gravity so that the transplanted lymph node can better exert its "pump" function which collects the edema fluid through the regenerated collateral lymphatic system to the venous system. This has been confirmed in long-term follow-up studies (20-22).

In our surgery design, the recipient site was designed to

Table 4 The circumference reduction rate of the patients

Patients	Circumference reduction rate				
	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5
1	43.2%	–41.2%	37.5%	–38.3%	11.8%
2	–7.7%/0.0%	2.8%/6.7%	6.2%/11.2%	4.2%/8.3%	4.2%/0.0%
3	–6.2%/–9.1%	8.7%/0.8%	4.9%/–2.4%	–0.9%/–1.1%	0.8%/0.1%
4	–1.4%/0.9%	–0.3%/–5.1%	4.7%/4.5%	0.9%/5.1%	2.3%/2.5%
5	3.3%	–20.0%	28.6%	31.3%	–4.0%
6	3.8%/4.3%	6.6%/14.7%	1.1%/2.4%	–5.6%/–2.9%	–6.3%/–2.9%
7	69.0%	61.5%	93.3%	–34.3%	–31.4%
8	77.5%	0.0%	48.1%	3.8%	68.6%
9	70.2%	39.8%	68.5%	38.6%	–14.7%
10	–8.9%/–1.2%	–8.1%/–1.5%	–1.6%/4.0%	–8.6%/5.3%	–5.1%/0.3%
11	100.0%	93.3%	79.2%	100.0%	–33.3%
12	–27.78%	–191.30%	–94.44%	25.00%	–169.44%
13	–55.56%	41.51%	19.15%	–16.98%	5.00%
14	42.86%	12.07%	28.21%	32.97%	44.00%
Mean ± SEM	15.64%±40.08%	11.79%±30.69%	20.25%±24.94%	7.73%±30.05%	–1.517%±16.75%

The negative percentage indicated that the follow-up value was larger than the first measured value at that plate. Plane 1: ankle; Plane 2: 10 cm above the ankle; Plane 3: 10 cm below the inferior pole of the patella; Plane 4: 10 cm above the superior pole of the patella; Plane 5: 20 cm above the superior pole of the patella. Use the ROUT test to reject outliers and analyze the results which are expressed as means ± SEM. SEM, standard error of mean.

be below the inguinal region to decrease the edema of the upper section of the thigh and perineum. Regarding the surgical strategy used, we considered that great omentum has potent abilities to secrete VGEF-C and absorb fluid. Moreover, since the outcome of two-segment VOLT is more effective than one-segment VOLT (16,23), we hypothesize that if the acquired omental volume is adequate, priority should be given to multi-segmental transplantation.

Furthermore, the different surgical areas should be treated differently to solve the edema of the calf and foot per time. Based on the MRL and ICG fluorescence results, we chose the anterior ankle region to perform LVA, and the medial calf or malleolus was selected as the VOLT recipient region. However, the proximal recipient area (i.e., thigh) usually suffered from more severe edema and fibrosis, so we transplanted the great omentum to obtain a better absorption capacity and improve the local microenvironment (24). Due to the large operation area, massive post-operation effusion will occur after this surgical procedure; therefore, much attention should be paid to reduce this harmful effect on the outcome of the surgery, such as placing negative pressure drainage apparatus during the surgery.

Conclusions

Our study showed that combining preoperative MRL and VOLT may help provide individualized and precise treatment and minimize surgical trauma and injury to healthy lymphatic vessels and nodes. We have demonstrated that VOLT has good postoperative outcomes for the treatment of cancer-related lower extremities lymphedema and can be recommended for surgical treatment of patients with such conditions.

Acknowledgments

Funding: This study was supported by the National Natural

Science Foundation of China (No. 82272508).

Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-1443/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics board of Xiangya Hospital, Central South University and informed consent was taken from all the patients.

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Cite this article as: Cheng G, Duan Y, Xiong Q, Liu W, Yu F, Qing L, Wu P, Gong L, Li X, Tang J. Clinical application of magnetic resonance lymphangiography in the vascularized omental lymph nodes transfer with or without lymphaticovenous anastomosis for cancer-related lower extremity lymphedema. Quant Imaging Med Surg 2023;13(9):5945-5957. doi: 10.21037/qims-22-1443

