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# Magnetic Resonance Lymphography at 3T: A Promising Noninvasive Approach to Characterise Inguinal Lymphatic Vessel Leakage

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ABSTRACT

*Purpose:* To explore the feasibility of using 3T high-resolution MR lymphangiography to characterize inguinal lymphatic vessel leakage (LVL).
*Materials and methods:* Sixteen patients with known inguinal LVL underwent 3T MR lymphangiography and $T_2$-weighted imaging. The presence or absence of inguinal LVL and the responsible lymphatic vessels were determined using the above imaging modalities and confirmed by surgical procedure. Afterwards, fifteen patients with recurring LVL following conservative treatment were referred to surgical intervention.
*Results:* Specific inguinal LVL enhancement patterns and leaking lymphatic vessels were detected in 15 of 16 patients. Compared to the SNR of enhanced lymph nodes, that of the enhanced LVL was significantly greater ($t = 7.149$, $p < 0.01$), thereby making it possible to differentiate between LVL sites and enhancing inguinal lymph nodes. Furthermore, the steepest contrast enhancement curve slope of enhanced LVL was lower than that of enhanced lymph nodes ($t = -2.860$, $p = 0.02$). After MR diagnosis, 15 patients successfully underwent open exploration and ligation of the leaking lymphatic vessel. Clinical follow-up did not demonstrate recurrence of lymphatic fluid in the groin.
*Conclusions:* High-resolution MR lymphangiography combined with $T_2$-weighted imaging is a promising approach to identifying specific features of lymphatic vessel leakage in the groin.


## Introduction

Inguinal lymphatic vessel leakage (LVL) is a severe complication of lymphatic vessel injury caused by surgery, lymph node biopsy or blunt trauma. With an incidence rate of 1–4%, LVL is uncommon, but may lead to lymphoedema of the lower extremities.[1–3] In cases when long-term conservative management of LVL fails, open surgical ligation of the leaking lymphatic vessels should be considered.[4] Before surgery, localisation and identification of the responsible lymphatic vessel(s) are necessary.[5] Direct lymphography, using traditional contrast-enhanced imaging modalities such as X-ray and lymphoscintigraphy, has been used to assess inguinal LVL. However, X-ray lymphography is limited by technical difficulties, procedural invasiveness and radiation exposure. Lymphoscintigraphy, while less invasive, is limited by its low sensitivity and poor anatomical visualisation.[6,7] Other conventional methods, such as ultrasonography and magnetic resonance (MR) imaging ($T_1$-weighted and $T_2$-weighted imaging), are able to identify the presence of fluid accretion in tissue, but do not distinguish between simple cysts, seromas, oedema and LVL.[8] Sensitive, less invasive and time-efficient magnetic resonance lymphangiography (MRL) has successfully been used to image lymphatic vessels in human subjects.[6,7] The purpose of this study is to characterise inguinal LVL and identify responsible lymphatic vessels in patients using a 3T MR scanner to produce T2-weighted images and MR lymphangiography.

## Materials and Methods

### *Patients*

Between 6 February 2009 and 17 March 2010, 16 patients, consisting of 6 males and 10 females with known LVL and a mean age of 34.5 ± 24.5 years, were recruited into this study. The diagnosis of LVL was confirmed by biochemical analysis of fluid taken from aspiration or drainage. The medical characteristics of the

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**Table 1**
Summary of the medical characteristics of patients involved in this study.

| Etiological factor | Case |
|---|---|
| Lymphadenectomy | 3 |
| Blunt trauma | 3 |
| Peripheral vascular surgery | 10 |
| *Conservative treatment* | |
| Aspiration and compression | 5 |
| Aspiration and sclerotherapy | 5 |
| Percutaneous drainage and compression | 6 |
| *Duration of LVL (weeks)* | |
| 4–8 | 8 |
| 9–16 | 6 |
| 17–24 | 2 |
| *Severity of lower limbs lymphedema* | |
| Stage I | 2 |
| Stage II | 10 |
| Late Stage II | 3 |
| *Underlying disease* | |
| Inguinal lymph node inflammatory hyperplasia | 3 |
| Vascular malformation | 6 |
| Varicose veins in lower extremity | 4 |
| none | 3 |

cohort are summarised in Table 1. Of the 16 patients, 15 had ipsilateral lower limb lymphoedema and one had no oedema. Clinical criteria of lymphoedema staging were done using the consensus document of the International Society of Lymphology 2009.[9] Exclusion criteria included patients with contraindications for magnetic resonance MR imaging, those allergic to Gd-contrast and/or those with renal insufficiency. Institutional Review Board approval and written consent forms were obtained for all the subjects prior to the initiation of this study.

*Surgical management*

A week after MR scanning, the 15 patients who had LVL recurrence after conservative treatment were referred to surgical intervention while the patient without leg lymphoedema continued conservative treatment. The simplified surgical procedure included injection of patent blue dye distally to the groin to mark the major lymphatic vessels that drain into the groin. This was followed by open surgical exploration of the groin and ligation of the patent endings of the vessels.

*MR imaging*

All patients underwent lymphangiography using a 3.0T MR scanner (Philips Medical Systems, Best, The Netherlands) and a six-channel, phased-array, and sensitivity-encoding reception coil. Accumulated fluid from LVL was localised prior to lymphangiography using turbo spin echo $T_2$-weighted images with fat suppression (TR/TE 3600/80 ms; thickness 5 mm; slices 24; flip angle 90°; field of view (FOV) 37 × 32 $cm^2$; acquisition matrix 320 × 304; spatial resolution 1.15 mm × 1.05 mm × 5 mm), which produced cross-sectional and coronal images of the inguinal region. For MR lymphangiography, a 3D THRIVE sequence (T1 high-resolution isotropic volume excitation, THRIVE) was performed. Pre- and post-contrast injection was done using the following parameters: TR/TE 23/2.1 ms; Flip angle 15°; FOV 38 × 36 $cm^2$; matrix sise 760 × 720 and voxel size 0.5 × 0.5 × 1.3 $mm^3$. *The reduction factor for sensitivity encoding was 2.0 and the number of signal average was 2*. Gadobenate dimeglumine (Gd-BOPTA, MultiHance, Bracco, Milan, Italy) mixed with 1% lidocaine (Gd-BOPTA:Lidocaine = 10:1) was injected intracutaneously using a 24-gauge needle into the inter-digital webs of the dorsum of the foot, with four injections into each foot. The volume injected at each point was about 1 ml. Each injection site was massaged for approximately 30 s immediately after administration of contrast material. After the massage, there was a deliberate 20 min delay. This amount of time was set based on a prior MR lymphography study.[10] Then, six dynamic scans were performed in the inguinal region to investigate contrast enhancement at the leakage sites in real time. The duration of each dynamic scan was approximately 3 min with no delay between scans.

*Image interpretation and data analysis*

The three-dimensional (3D) THRIVE images were reconstructed using maximum intensity projection (MIP). MR lymphangiography images were interpreted by two experienced radiologists, who evaluated the images simultaneously until a consensus was reached. The presence or absence of inguinal LVL and its associated lymphatic vessels were identified. The number of leaking lymphatic vessels was then compared between the three subgroups of patients: those who had lymphadenectomy, those with trauma and those who had peripheral vascular surgery. The LVL site was defined as an area with accumulated fluid as represented by high signal intensity on $T_2$-weighted imaging and extravasation of contrast material on post-contrast MIP images. Leaking lymphatic vessels were defined as vessels with a continuous course along the inner thigh with extension to the inguinal region ending abruptly at the LVL site. Differentiation between LVL sites and enhancing inguinal lymph nodes was determined by comparing the signal-to-noise ratio (SNR) and time-signal intensity curves (TICs) obtained from the dynamic THRIVE source images. The operator-defined regions of interest (ROIs) were placed within the lymph nodes and leakage sites at areas of greatest enhancement. All ROIs were placed by two radiologists. A signal intensity of the air surrounding the body (ROI, 300 $mm^2$) was obtained to estimate the background signal. The SNR was determined by dividing the mean SI by the standard deviation (SD) of noise measured outside the patient. TICs were constructed from signal intensity (SI) values obtained from operator-defined ROIs. The contrast enhancement curve with the steepest slope was used to measure the rate of contrast flow within the LVL sites and lymph nodes. The rate is mathematically expressed by the following equation:

$$\text{Steepest slope (in percent per minute)} = (SI_{max} - SI_{TI})/(T_{max} - T1)$$

where $SI_{max}$ and $SI_{T1}$ are the values of SI on the steepest slope at the corresponding time points $T_{max}$ and T1. $T_{max}$ represents the time at which peak enhancement was achieved and T1 is the time at which the first dynamic scan was initiated. Statistical analysis was performed using SPSS 11.0 for Windows (SPSS Inc., Chicago, IL, USA). A Student's *t*-test was used to compare the significance of the differences between mean values, and ANOVA test was used to determine whether the differences between the three subgroups were significant. A value of $P < 0.05$ was taken to indicate significance.

## Results

All patients completed the 45-min examination successfully and two experienced radiologists confirmed that the quality of the images was sufficient for analysis. No systemic or local complications were observed during or after the examinations. The LVL sites on $T_2$-weighted images showed encysted or irregular patchy areas with high signal intensity in all 16 patients (Figs. 1–4). On post-contrast 3D THRIVE images, extravasation of contrast material