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Practical considerations in starting a peripheral lymphedema magnetic resonance imaging program

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Abstract

The management of chronic peripheral lymphedema benefits from a multidisciplinary approach in which magnetic resonance imaging (MRI) can play a key role. The imaging has been well described in the literature (including this journal), but the process for starting a novel imaging service line is complex. Participants in this process, including radiologists, imaging technical staff, information technologists, and revenue cycle managers, must be engaged and work in harmony to achieve success. The purpose of this article is to detail the building blocks and steps in starting a peripheral lymphedema MRI program, how our process evolved, and lessons learned along the way.

Keywords: Magnetic resonance lymphangiography, magnetic resonance lymphography, lymphedema, radiology service line

INTRODUCTION

Limb lymphedema is a chronic condition characterized by accumulation of protein-rich fluid in the interstitium, adipose deposition, and inflammation leading to fibrosis and sclerosis[1-3]. For the plastic surgeon to most effectively manage the chronic lymphedema patient with modern microsurgical approaches such as lymphovenous bypass or vascularized lymph node transfer, peripheral MR lymphangiography (MRL) is a highly useful tool to noninvasively assess the anatomy and function of the lymphatic system, but is not widely available at most centers[4-8].

MRL is an MR examination in which the peripheral lymphatic channels and subcutaneous soft tissues of an extremity are evaluated in a multiparametric fashion[9]. A multisequence protocol provides an anatomical assessment of fluid and fat distribution, lymphatic contrast injection and subsequent imaging of lymphatic drainage, and intravenous contrast injection and subsequent imaging to assess venous outflow, comprehensively evaluating the extremity to guide treatment planning[5,10]. This manuscript will detail how to start a peripheral MRL program using an organized, methodical team-based approach, which will be divided into visioning, analysis, implementation, and reflection.

VISIONING PHASE

During this phase, the collaboration of key stakeholders is critical in crafting a vision[11]. In this case, the vision is to improve the care of lymphedema patients by offering targeted surgical therapy, guided in part by the diagnostic imaging of MRL. Collaborating with a radiologist to champion this effort is imperative, as the champion will identify colleagues within the radiology infrastructure whose shared efforts will be crucial in the success of the venture, such as radiologists who will perform the web space lymphatic injection and radiologists who will interpret the MRL exam (they may be the same individual or different), technical staff to build and perform the MR protocol, and ancillary staff to schedule, protocol, and bill for these novel exams[12]. Having an answer to every possible question is less important at this stage than openly communicating with the radiology department leadership about why this vision matters.

ANALYTICAL PHASE

During this phase, the radiology champion may consider conducting a SWOT (strengths, weaknesses, opportunities and threats) analysis to determine current strengths and weaknesses and potential opportunities and threats[13]. In our case, strengths included a new state-of-the-art MR scanner with the latest technologies, MR technologists willing, familiar, and capable of building new MR protocols in collaboration with radiologists, a plastic surgery referral service strongly supportive of this initiative, and information technology (IT) and billing support. Weaknesses included the complexity of establishing a new service line, determining who would have the expertise, willingness, and availability to perform lymphatic injections, and expertise in interpreting an unfamiliar exam. Opportunities include being able to offer and market a unique new service line, growth of clinical revenue, and esprit de corps in collaborating to care for these clinically challenging patients. Threats include loss of patients to competitors offering these clinical services/imaging and loss of productivity in the lead-up to developing an efficient process for performing and interpreting these exams.

At this stage, we identified the key stakeholders outlined in Figure 1. We recognized that our musculoskeletal radiologists were ideally positioned to perform the web space lymphatic magnetic resonance imaging (MRI) contrast injection both physically, in close proximity to the MR scanners, and technically, as they are adept and comfortable in performing injections. A specific MR scanner was designated for performing these exams at two different campuses because of the availability of specific MR coils (a "runoff" or whole body coil to provide adequate anatomic coverage of the pelvic/lower extremity) and a large field of view needed to image the extremities efficiently[14]. An advanced MR technologist was recruited to assist in building the MRI protocol on the scanner and to perform the initial examinations with the supervision of the radiology champion. Our IT group was consulted early in the process to create the codes that would be needed to order these exams in the health information management system (HIMS) and modify the electronic form within the HIMS used by radiologists to protocol the exams. We also worked closely with IT to eventually build display protocols in the radiology picture archival and communication system (PACS) to display these exams for efficient viewing and interpretation. Scheduling was also more complex than a standard MR exam because of the need for injection of the lymphatic

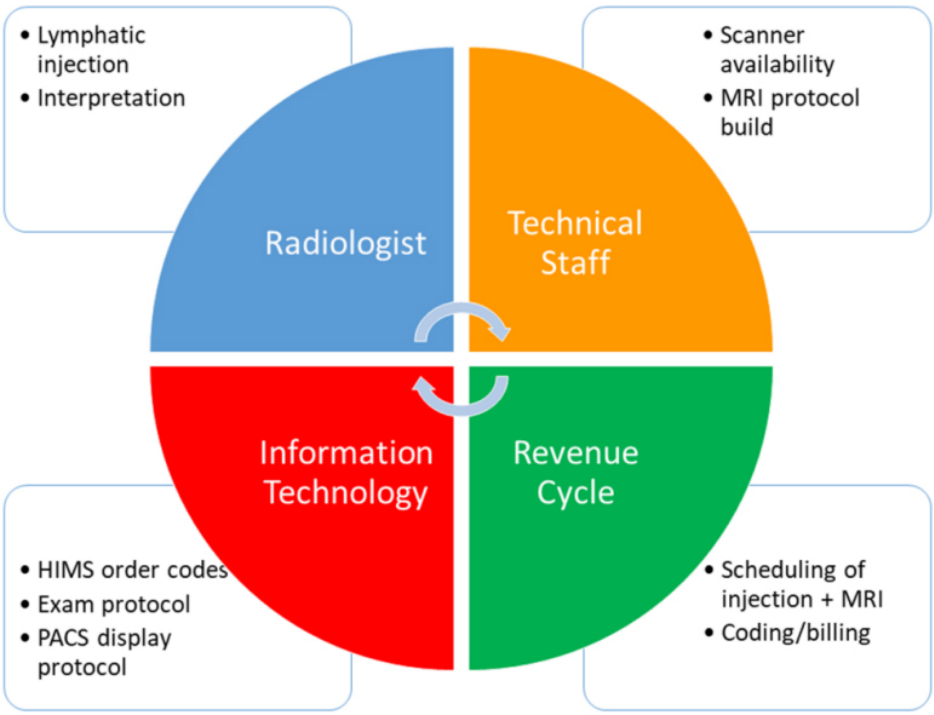

Figure 1. Key radiology stakeholders in establishing a peripheral MR lymphangiography program. MRI: Magnetic resonance imaging; HIMS: health information management system; PACS: picture archival and communication system.

contrast to take place before the patient's MR exam, but this workflow should be familiar to musculoskeletal radiologists who perform MR arthrograms with a similar workflow. Extensive discussions were undertaken with the coding and billing department to ensure that these exams would be coded and billed appropriately to minimize issues with insurance preauthorization and payment. The injection portion of the exam, which is performed without imaging guidance, may also be billable as a separate procedure. The design of this process must take into account the institutional, local, and national healthcare environment and guidelines, and will vary from site to site.

We achieved the following milestones during the development phase of establishing a new MRL service line:

- 4 months out - initial meetings to establish goal and vision

- 3 months out - configure HIMS ordering, scheduling, protocoling, and billing

- 2 months out - build protocol, plastic surgery begins seeing lymphedema patients in clinic and ordering exams

- 1 month out - establish a clinical workflow for injection, MR protocol, scheduling patients

- "Go Live": first exam

IMPLEMENTATION PHASE

Our first clinical MRL exam took place approximately 5 months after the initiation of the project. As with any new endeavor, expected and unexpected challenges were encountered. The radiologist performing the webspace injections found that using a single 25-gauge syringe for injections was far simpler than multiple 30 gauge tuberculosis syringes. Reconstruction of the numerous imaging data sets on the scanner was lengthier than anticipated, and the volume of images for the first exam numbered over 25,000, creating difficulties in actually loading and reading the exam on PACS.

Iterative development of the clinical and imaging protocol has been an essential component of the success of the MRL imaging program. As we accrued more experience, several changes were made to the imaging protocol, including reducing the number of dynamic MRL acquisitions from every 5 min to every 10 min over a 30-min span, reducing the overall number of images. The upper extremity protocol was modified to include a large field of view image to allow at least a partial comparison of both upper extremities [Figure 2] and the imaging plane was changed from sagittal to coronal to make interpretation more straightforward. We developed a patient educational flyer [Figure 3] to prepare patients for what to expect during the exam and began having patients administer topical lidocaine to the injection web spaces prior to the exam to decrease discomfort. As we moved to a new PACS, a new display protocol was developed to make image interpretation more efficient.

Our current state is performing approximately 7 to 8 MRL exams per month, roughly 60% of the upper extremities and 40% of the lower extremities. The current MRL protocols are listed in Tables 1 and 2 for reference, with sample images in Figure 4. After initially only being performed by a single MR technologist at each site, other technologists now have the training and experience to perform diagnostic exams. A single radiologist still interprets most MRL exams in our practice, but educational material has been developed for other radiologists who have expressed interest to begin learning to interpret these exams.

REFLECTION

Establishing an MRL imaging program is not an impossible task but one that can be achieved with detailed organization. Every radiology practice is structured differently and what worked for us may not be feasible or advantageous for others. However, certain factors are important to keep in mind when setting up an MRL imaging program.

The lymphatic injection component of the exam can prove to be a difficult logistical challenge. Maximizing flexibility for the physicians performing the injections aids in creating a successful partnership. Rather than setting up our exam to acquire images prior to contrast injection, which would require the injecting radiologist to be available at short notice to perform the injection with the patient already on the scanner, we decided to have the exam start only after the radiologist performed the injection, giving them greater flexibility. Our entire group of musculoskeletal radiologists participate in performing the injections, simplifying the scheduling of these exams.

Positioning of patients for the upper extremity exam can also be variable, depending on what the patient can tolerate for a 45- to 60-min exam. Ideally, a patient would be able to keep their arm raised above their head, but this is frequently not feasible and the arm is then imaged at the side, creating challenges with the field of view and uniformity of image quality. Performing the exam on a newer large bore (70 cm diameter) MR scanner with a larger field of view is helpful for optimizing image quality.

Table 1. MR lymphangiography sequence parameters at 1.5 Tesla

	Coronal T2-weighted single-shot fast spin-echo	Coronal heavily T2-weighted fast spin-echo	Coronal T1-weighted Dixon 3D spoiled gradient echo
TR/TE (ms)	1000/100	2300/800	6.79/2.39
Flip angle (°)	150	110	10
Number of slices per station	60	192	192
Slice thickness (mm)	4	1.5	1.5
Field of view (mm)	500 × 500	500 × 500	500 × 500
Matrix	384 × 384	512 × 512	384 × 360
Voxel size (mm)	1.3 × 1.3 × 4	1 × 1 × 1.5	1.3 × 1.3 × 1.5
Acquisition time (s)	60	250	100
Role	Overview of water and fat accumulation	Assessment of fluid accumulation	Lymphatic and venous assessment

Table 2. MR lymphangiography protocol at 1.5 Tesla

Sequence/Step	Comments
Lymphatic intracutaneous injection of dilute gadolinium (6 mL gadolinium + 2 mL saline total), 1 mL per web space, via 25 gauge syringe, followed by massage of web spaces to facilitate lymphatic uptake	
Coronal T2-weighted single-shot fast-spin echo	Reconstruct composed sequence of all stations
Coronal heavily T2-weighted fast-spin echo	Reconstruct composed sequence of all stations and maximum intensity projection; can perform in the time interval between dynamic sequences below
Coronal T1-weighted DIXON 3D spoiled gradient echo; image every 10 minutes (0, 10, 20, 30)	Reconstruct water-only and fat-only images
Intravenous injection of gadolinium contrast (weight-based dose) for venography	
Coronal T1-weighted DIXON 3D spoiled gradient echo venogram	Reconstruct water-only and fat-only images; 120-second delay after contrast injection to ensure uniform venous enhancement
Coronal T2-single shot fast spin echo (large field of view with both arms)	Upper extremity exam only, to quantify fat accumulation compared to unaffected extremity

Two stations are obtained for the upper extremity using two phased array surface coils. Three stations are obtained for the lower extremities (to include the pelvis), using a phased array surface coil over the pelvis and a peripheral angiography coil over both lower extremities.

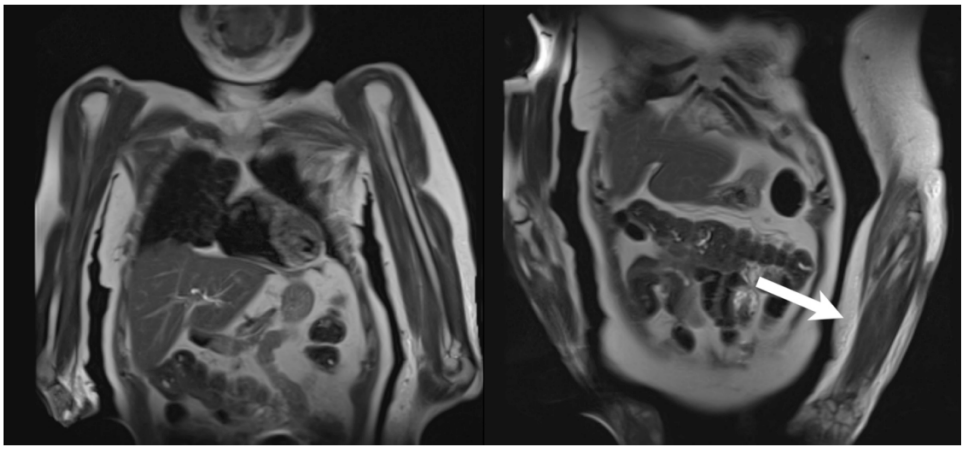

Figure 2. Coronal T2-weighted single-shot fast spin-echo large field of view MRI images of both upper extremities, with the unaffected extremity brought into the imaged field of view, facilitate comparison of fat accumulation in the affected extremity (arrow) with the unaffected extremity. MRI: Magnetic resonance imaging.

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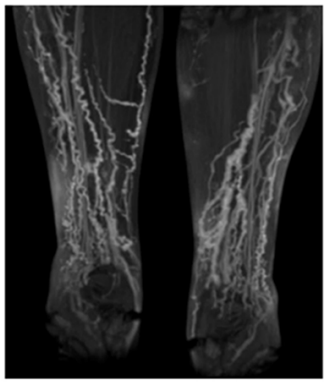
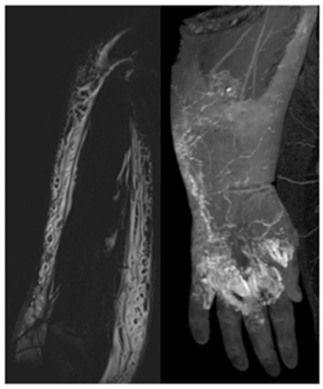
MR Lymphangiography

What is MR Lymphangiography?

- MR Lymphangiography is an MRI study designed to diagnose and stage the severity of lymphedema in the legs or arm and help guide your physician's treatment plan
- The study involves injection of gadolinium contrast material into the web spaces between your fingers or toes, depending on the type of study, to be able to see lymphatic vessels in the arm or legs
- The doctor will clean your skin, insert a small needle through the skin into the web spaces of either the hand or both feet, and inject a small amount of contrast into each web space, to be taken up by lymphatic vessels that can be imaged with MRI.



- After the injection, you will be positioned in the MRI scanner with a coil covering either your legs and pelvis or your arms and chest, depending on the type of study.
- If you are getting an upper extremity MR Lymphangiogram, the arm may be placed either at your side or above your head, depending on how best you can be positioned to obtain the highest quality study.
- If you are getting a lower extremity MR Lymphangiogram, you will be lying on your back in the scanner with your legs positioned normally.



- MR images will be obtained over the next 30 minutes to track the flow of lymphatic contrast
- Intravenous gadolinium contrast will then be injected and more MR images will be obtained to assess the veins in the legs or arm.
- The exam will take approximately 1-1.5 hours to complete from when the process of injecting the contrast into the web spaces begins.

Why do you need an MR Lymphangiogram?

An MR Lymphangiogram may help your physicians:

- Find out whether swelling in your arm or leg is due to fluid or fat accumulation
- Find out if the lymphatic vessels are enlarged or blocked within the arm or leg
- Plan further treatment for your lymphedema

Preparation for an MR Lymphangiogram:

- Review of allergies: It is very important that your physicians be aware of any allergies you may have, particularly to gadolinium contrast used for MRI. If you are allergic to gadolinium contrast used for MRI, you may either need to be premedicated to reduce the risk/severity of an allergic reaction during the study or may not be able to safely obtain the study, depending on the type of allergic reaction. Please consult with your doctor.

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Figure 3. Patient educational flyer informing them of what to expect for their MRL exam. MRL: Magnetic resonance imaging.

Figure 4. Sample lower extremity MR lymphangiography exam in a 67-year-old man with long-standing unilateral right lower extremity lymphedema. (A) Coronal T2-weighted single-shot fast-spin echo MRI shows unilateral right lower extremity lymphedema characterized by both excess fat and water accumulation. (B) Coronal heavily T2-weighted fast spin-echo MRI highlights the distribution of fluid accumulation with greater conspicuity. (C) Coronal T1-weighted Dixon water-only 3D spoiled gradient echo MRI obtained 30 min after lymphatic contrast injection shows dilated lymphatics channels in the medial right ankle and thigh (arrows). (D) Coronal T1-weighted Dixon water-only 3D spoiled gradient echo MRI venogram obtained 120 s after intravenous contrast administration shows normal venous outflow in the right lower extremity. MRI: Magnetic resonance imaging.

Venous contamination after lymphatic injection is common and encountered on nearly every exam, likely due to intracutaneous transit of gadolinium into the veins[9,15]. We overcome this with the use of a delayed venogram to help differentiate superficial veins, which enhance more brightly after intravenous contrast injection, from lymphatic channels [Figure 5]. This is performed as the final acquisition (approximately 40 min after lymphatic contrast injection) 120 s after administration of intravenous contrast to allow for uniform venous enhancement. Some centers use a dual-agent relaxivity contrast (DARC) MRL technique in which intravenous ferumoxytol contrast is administered and images obtained in such a way to null blood vessel signal, limiting enhancement only to lymphatic structures[16,17]. However, the US Food and Drug Administration (FDA) warns of potentially fatal allergic reactions to ferumoxytol and urges IV infusion over 15 min and close monitoring for signs of allergic reactions, including blood pressure and pulse monitoring, for at least 30 min following infusion, creating additional logistical challenges if used[18].

Finally, although direct cost-benefit analysis is not available locally nor previously evaluated in the literature, MRL is an expensive proposition, both in terms of the time and energy invested in starting a program and the actual cost of the exam to a patient. Before embarking on such a journey, factors such as surgical expertise, a comprehensive care infrastructure including lymphatic therapy, and adequate demand within the local population should be assessed to ensure sufficient need and volume as to support the new program.

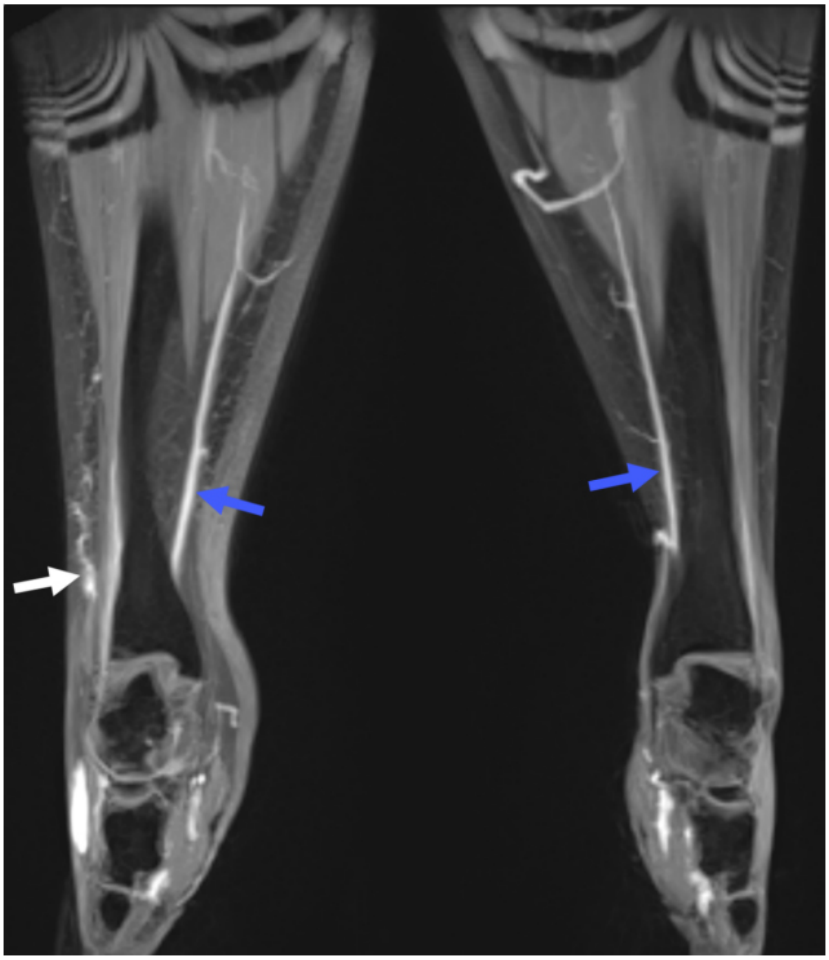

Figure 5. Overcoming venous contamination in a 70-year-old woman with right lower extremity lymphedema. A coronal T1-weighted Dixon water-only 3D spoiled gradient echo MRI venogram obtained 120 s after intravenous contrast administration shows greater enhancement of veins (blue arrows) relative to dilated lymphatic channels in the right ankle (white arrows). This may be helpful in distinguishing lymphatics from veins at the venographic phase. MRI: Magnetic resonance imaging.

CONCLUSION

MRL provides valuable noninvasive diagnostic information to the plastic surgeon to guide therapy of peripheral lymphedema. Establishing an MRL imaging program requires a multidisciplinary collaboration with clearly defined goals, a radiology champion to identify and work with stakeholders within radiology to build the components needed to schedule, perform, and interpret exams, and continuous iteration to improve the workflow to provide better clinical care to patients with chronic peripheral lymphedema.

DECLARATIONS

Author's contribution

The author contributed solely to this article.

Availability of data and materials

Not applicable.

Financial support and sponsorship
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Conflicts of interest
The author declared that there are no conflicts of interest.

Ethical approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

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