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The utility of Dynamic Contrast Enhanced Intranodal MR Lymphangiography in the investigation of primary lymphatic anomalies.

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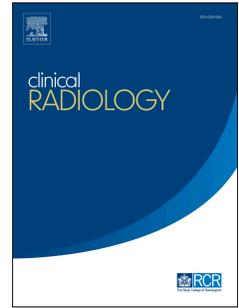
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The utility of Dynamic Contrast Enhanced Intranodal MR Lymphangiography in the investigation of primary lymphatic anomalies.

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Abbreviations:

CNR – Contrast-to-noise ratio

DCMRL – Dynamic Contrast Enhanced Intranodal Magnetic Resonance Lymphangiography

MIP – Maximum Intensity Projection

MR – Magnetic resonance

MRA – Magnetic Resonance Angiography

MRL – Magnetic Resonance Lymphangiography

SCID – Severe combined immunodeficiency

SPGR – Spoiled Gradient Echo

TD – Thoracic Duct

The utility of Dynamic Contrast Enhanced Intranodal MR Lymphangiography in the investigation of primary lymphatic anomalies.

Abstract

Background: Primary lymphatic anomalies are often complicated by central lymphatic abnormalities. Intranodal dynamic contrast enhanced MR lymphangiography (DCMRL) is a relatively new technique for imaging the central lymphatic system. Historically, the only method of imaging the central lymphatics well was with pedal lymphangiography, which is technically challenging, time consuming, involves the use of ionising radiation and has risks associated with the use of lipiodol. The treatment options for primary lymphatic disorders have also been limited to symptomatic management.

Purpose: To describe the technique of DCMRL to identify central lymphatic abnormalities in patients with primary lymphatic anomalies and discuss utility of the findings.

Materials and Methods: 28 patients with primary lymphatic abnormalities underwent dynamic MR imaging following injection of gadolinium directly into inguinal lymph nodes at a tertiary lymphovascular referral centre.

Results: Technical success was achieved in 23 patients (82.1%). Pathological imaging findings included obstructed, hypoplastic or absent lymphatic channels with collateralisation/rerouting or reflux of flow, lymphangiectasia, lymphatic pseudoaneurysms and lymph leaks. Protocol modifications for improved imaging are highlighted including technical aspects of lymph node injection, image acquisition and MRI parameters. In two patients, imaging findings warranted embolization of the abnormal lymphatic channels with subsequent symptomatic improvement.

Conclusion: DCMRL has been shown to be a safe, reproducible technique in patients with primary lymphatic anomalies enabling imaging of the central lymphatic system.

1 **The utility of Dynamic Contrast Enhanced Intranodal MR Lymphangiography in the**
2 **investigation of primary lymphatic anomalies.**

3 **Introduction**

4 Intranodal dynamic contrast enhanced MR lymphangiography (DCMRL) is a relatively new technique

5 enabling imaging of the central lymphatics via injection of contrast directly into inguinal lymph

6 nodes. Lymphoscintigraphy remains the investigation of choice for diagnosis in lymphatic disorders

7 but does not give detailed imaging of the central lymphatics.1–3 Pedal lymphangiography with

8 Lipiodol whereby contrast was injected directly into lymphatics in the foot which had been surgically

9 exposed is invasive, very time consuming, involves ionising radiation, and can result in lipiodol

10 embolization.4 **XXXXXX** NHS Foundation Trust is recognised as a national referral centre in the UK

11 for Primary Lymphatic Anomalies. Many of these genetically determined forms of primary lymphatic

12 anomalies have central lymphatic abnormalities associated with (or causing) peripheral

13 lymphoedema.5–8 These lymphatic abnormalities may not be clinically obvious yet are important to

14 diagnose both for correct phenotyping and for ongoing management.9 Although described for other

15 indications, there remains a paucity of data exploring DCMRL's utility in patients with primary

16 lymphatic anomalies.10–12 The purpose of this paper is to describe the method and utility of this

17 technique in imaging central lymphatic abnormalities in patients with primary lymphatic anomalies.

18 **Materials and Methods**

19 Patients

20 Patients were referred for DCMRL if they had a diagnosis of a primary lymphatic anomaly (chylous

21 reflux, significant lymphoedema with a suggestion of obstruction on lymphoscintigraphy,

22 chylothorax, chylopericardium or chylous ascites).

23 DCMRL technique

24 Inguinal lymph node puncture was carried out under ultrasound guidance using a shallow angle of

25 entry with a long subcutaneous tract to obtain a stable needle position with a 23G spinal needle (BD,

26 Franklin Lakes, NJ). Ideally, a minimum of one needle was sited in each groin. Where nodes were

27 easily visualised and patients tolerated placement well, a third needle was sited to increase likelihood

28 of contrast uptake. Satisfactory position within the lymph node was then confirmed using injection of

29 1ml of SonoVue (sulphur hexafluoride microbubbles) ultrasound contrast (Bracco Spa, Milan, Italy)

30 mixed with 2ml of 0.25% Chirocaine (levobupivacaine) for local anaesthesia. The needles were then

31 secured in place with dressings and connecting tubing attached with syringes primed with Gadoteric

32 acid (Dotarem®; Guerbet, France).

33 <u>Magnetic Resonance Imaging</u>

34 For all studies, MR imaging was performed using a clinical 3.0T MRI system Philips Achieva 3.0T TX

35 and a 16-element phased array torso coil for signal reception. The imaging protocol (**Table 1**) consists

36 of initial non-contrast sequences followed by dynamic contrast enhanced imaging.

37 Non-contrast imaging of the abdomen and pelvis begins with a 2D T_2-weighted breath-held turbo spin

38 echo (TSE) acquisition for identification of gross abnormalities (e.g., fluid accumulations), 3D image

39 planning, and allows for the identification of incidental findings. A 3D heavily T_2-weighted TSE

40 sequence follows, for which only very long T_2 compartments retain reasonable signal intensity. Finally,

41 a pre-contrast 3D T_1-weighted spoiled gradient echo (SPGR) image was acquired. The non-contrast T2-

42 weighted images were assessed for the presence or absence of ascites, pleural and pericardial effusions,

43 oedema in the soft tissues and the presence of masses of lymphatic nature, and for how well the

44 lymphatics were visualised.

45 Slow injection (over 1-2 minutes) of 4 - 9ml of undiluted 279.32 mg/ml Gadoteric acid (Dotarem®;

46 Guerbet, France) was then carried out simultaneously via each needle placed in an inguinal lymph node,

47 followed by dynamic T_1-weighted imaging post-injection to depict contrast dispersion over time (each

48 acquisition lasted 0.5 minutes).A maximum of 3 needles were placed and maximum total dose of 18ml

49 of Gadoteric acid injected. In cases where contrast was initially difficult to visualise, T_1-weighted

50 Dixon images, of higher spatial resolution and larger field of view than the spoiled gradient echo

51 sequences, were acquired. Imaging initially focussed on the pelvis and lower abdomen until contrast

52 was seen to leave this region (variable), at which point the coil was repositioned to continue imaging to

53   the thoracic duct termination. The post-contrast T1weighted images were evaluated for presence or

54   absence of lymphatic vessels, anatomical distribution of the contrast (normal or abnormal), reflux,

55   lymphatic pseudoaneurysms, leakage of lymphatic fluid, rerouting/ collateralisation, and the presence

56   of dermal backflow of contrast. All image volumes were reformatted as maximum intensity projections

57   (MIPs) for review, coronal projections for T_1-weighted image series and radial projections for the T_2-

58   weighted images. Total imaging time ranged from approx. 30 – 90 minutes, however an hour was typical

59   (average ± standard deviation = 53 ± 13 min), variability was secondary to individual variation in the

60   post-contrast acquisition time.

61

62   **Results**

63   From January 2018 to December 2022, 28 patients were imaged. A summary of the results and

64   underlying primary lymphatic diagnosis is provided in **Table 2**. The imaging findings are described

65   below. No contrast reactions were observed and no patients terminated the examination due to pain,

66   no delayed complications were reported during post procedure follow-up.

67

68   Non contrast:

69   From the T2 non-contrast imaging, central lymphatic channels could not be identified in 10 of the 28

70   patients. Of the remaining 18 patients, the lymphatic channels could be seen but were faint and not

71   deemed to be sufficiently visualised to be diagnostically helpful in 16 patients **[Figure 1].** The

72   lymphatic channels were seen well in only two patients **[Figure 2a].**

73

74   Post contrast:

75   Technical success visualising the central lymphatics was achieved in 23 patients (82.1%). In five

76   patients, injection was performed unilaterally due to absence/ inability to identify targetable lymph

77   nodes on the contralateral groin either due to previous surgical removal of nodes or extensive oedema

78   [**Table 2**]. Central lymphatics were successfully visualised in all five patients with contrast noted on

79   the non-injected side signifying reflux (Cases 10, 26 and 28) [**Figure 2b**], normal unilateral uptake

80   with normal thoracic duct (Case 20), and superficial re-routing indicating obstructed main drainage

81   routes (Case 13).

82   In the remaining 23 patients, bilateral injections were performed. Of these,

83   a) In 5 patients (Cases 1, 2, 9, 15 and 17), no propagation of contrast was seen bilaterally. These

84   were considered technical failures.

85   b) In 3 patients (Cases 5, 16, and 19), bilateral uptake of contrast was noted, and the imaging

86   showed normal central lymphatics.

87   c) In 6 patients (Cases 3, 6, 7, 8, 11, and 25), bilateral uptake of contrast was noted with

88   abnormalities detected (termination of the thoracic duct (TD), absent filling of TD,

89   lymphopseudoaneurysms, lymphangiectasia, obstructed or absent lymphatic channels with

90   collateralisation).

91   d) In 9 patients, propagation of contrast was absent on **one** of the injected sides in the groin

92   (bilateral injections performed). Of these, 2 patients (Cases 21 and 22) showed normal lumbar

93   and iliac lymphatics on the side with contrast propagation with normal appearances of the TD.

94   The remaining 7 had a range of abnormalities including reflux into the ipsilateral pelvis and

95   limb which was the limb affected with lymphoedema (Case 23), collateralisation with re-

96   routing of the lymphatic fluid to the distal lymphatic channels (Cases 14, 18 and 27) and

97   lymphopseudoaneurysms (Cases 12 and 24) and a patient with Noonan syndrome with

98   abnormal mediastinal and pulmonary lymphatic perfusion and rapid flow of contrast to the

99   terminal TD (Case 4).

100 **Discussion**

101 The ability to image the central lymphatic system in this group of patients has led to an understanding

102 of the anatomy of their central lymphatics which was previously unknown. The discussion is divided

103 into technical factors and the lymphatic findings.

104 1. Review of DCMRL procedures

105 **Selection of lymph node for contrast injection:** Subjectively abnormal, absent and hypoplastic

106 lymph nodes are more common in patients with primary lymphatic disorders with target nodes

107 frequently < 1cm in size. Ideal needle tip positioning is at the corticomedullary junction. Lymph node

108 enhancement and efferent flow after injection of ultrasound contrast confirms good positioning. [13–15]

109 The chirocaine alleviates pain that is otherwise experienced on injection of Gadoteric acid

110 intranodally.

111 **Securing the needles in position**: We noted ease of needle displacement in our initial studies (loss of

112 position between placement and fixation, extravasation noted in the groin) with no uptake of contrast

113 on the displaced side. Thus, if patients tolerated needle placement well, up to 3 needles in one groin

114 were placed to maximise chances of introducing contrast into lymph nodes. This was only carried out

115 in 3 patients. Initial studies had an attempted injection of 9 ml of Gadoteric acid into each node,

116 however reduction to 4 ml injected into each node was found to still provide satisfactory contrast

117 visualisation with improved tolerance from patients. We found that avoiding placement of needles in

118 the groin crease, positioning the coil above the tip of the needles and the use of connecting tubing

119 primed with contrast and attached at needle placement also stops the needles becoming displaced

120 when connecting a syringe to the needle for injection in the MRI scanner.

121 **Non-contrast T_2 weighted Magnetic Resonance Imaging:** Unlike most bodily tissues, lymph can be

122 expected to retain reasonable signal in long echo time scans given its T_2 time of approx. 610 msec at

123 3T[16]. These images provide a high contrast-to-noise ratio (CNR) for fluid containing regions and are

124 thus especially useful for identifying areas of lymphatic fluid accumulation [**Figure 3**]. Despite a

125 reduced CNR, moderately T_2-weighted 2D sequences were also found to be beneficial as the fluid

126   accumulations could be observed in the context of the underlying anatomy. Sites setting up their own

127   MRL protocols may wish to consider whether two acquisitions are required in their context,

128   particularly if scanner time is limited. Acceleration techniques such as partial Fourier reconstruction

129   can also be applied to reduce imaging time but can reduce image SNR and introduce artefacts.17

130   Other non-contrast approaches have been described to assess the lymphatics in the abdomen

131   including a recent attempt using balanced steady state free-process (bSSFP).18 In this paper, cardiac

132   triggered and respiratory navigated bSSFP images facilitated improved visualisation of the

133   lymphatics compared to respiratory triggered heavily T_2 weighted TSE. bSSFP sequences exhibit a

134   complex T_2/T_1 weighting in which fluids (lymph, CSF, blood) are high signal. We therefore chose not

135   to employ bSSFP over TSE given the t high blood signal which could cause confusion in differentiating

136   lymphatic from the vascular structures.

137   **Contrast-enhanced T_1-weighted Magnetic Resonance Imaging:** Administration of Gadoteric acid

138   into the lymphatics reduces the long T_1 time of lymph sufficiently to be observed in dynamic T_1-

139   weighted images where the passage of contrast agent within the lymphatics needs to be observed over

140   time [**Figure 3**].16. We employed Gadoteric acid due to a combination of local availability and its

141   strong safety profile.19 Similar enhancement with a reduced volume of contrast agent may be possible

142   using a similarly safe agent with greater r_1 relaxivity such as Gadoteridol or Gadobutrol20 but

143   requires *in-vivo* validation for lymphatic applications.

144   With high spatial and temporal resolution [**Table 1**], the spoiled gradient echo sequence was the

145   default sequence for our dynamic imaging, Dixon based images are less affected by inhomogeneities

146   outside the scanner isocentre but maintain high quality fat suppression, DIXON imaging was acquired

147   in several cases and were particularly useful for cases in which contrast agent was seen to re-route via

148   superficial lymphatic vessels [**Figure 4**]. A spoiled gradient echo sequence was chosen as the

149   standard sequence for the dynamic post-contrast imaging as DIXON imaging takes longer to

150   reconstruct and therefore limits the ability for on-table evaluation of the findings.

151 Some sites performing DCMRL have employed keyhole imaging to accelerate their T_1-weighted

152 dynamic imaging21. However, care must be taken to ensure sufficient high spatial frequency data is

153 captured to appropriately reconstruct small structures such as lymphatics and further work in this area

154 is required. Additionally, methods of motion artefact reduction have been employed by several centres

155 (breath-held T_1-weighted contrast enhanced scans, and respiratory or cardiac gating/triggering T_2

156 scans) to reduce motion artefacts and improve image quality, at the expense of extend imaging times

157 and can be considered if time is not a limiting factor.22–29

158 2. Observation of Lymphatic Abnormalities

159 **Absence of contrast uptake:** 5 patients with absent bilateral contrast uptake were also found to have

160 no uptake beyond the ilioinguinal nodes on pedal lymphoscintigraphy. Thus, although considered

161 technical failures, this may in fact be a true finding. It appears possible that those with no uptake on

162 pedal lymphoscintigraphy may be unlikely to show uptake with DCMRL although numbers are too

163 small to make definitive conclusions. Of the 9 patients in whom contrast uptake was absent on one

164 side, this may be due to an absence, functional aplasia or hypoplasia of the lymphatic system,

165 technical failure to access the lymph nodes, or needle displacement. Hypoplastic or absent lymphatics

166 has been shown to be useful for confirming or completing the clinical diagnosis in conditions with

167 primary lymphatic anomalies.30

168 **Dynamic aspect of DCMRL allows for more detailed study of flow in the lymphatics and**

169 **therapy compared to non-contrast MR imaging and lymphoscintigraphy.** For example, 3 of the

170 patients found to have reflux into the contralateral side was not known about prior to DCMRL. Two

171 of these patients subsequently underwent glue embolization [**Figure 5**] with improvement in number

172 of lymphatic blisters and volume of chylous leak, and no further episodes of infection on the affected

173 side in both patients.31

174 5 patients demonstrated superficial re-routing of the lymphatics confirming obstruction of their

175 normal lymphatic pathways [**Figure 6** and **Table 2**]. Confirmation of central lymphatic obstruction

176 can then lead to exploration of surgical options such as lymphovenous anastomosis.32,33

177   An inherent difficulty arising from investigating rare diseases is the relatively small numbers of

178   patients with each condition, however the imaging has led to improved understanding of the

179   mechanisms behind lymphatic anomalies and changes in patient management. The development of the

180   technique has resulted in refinements over time which has made the data more heterogenous. Our

181   experience is presented here to facilitate the development of DCMRL services elsewhere within the

182   UK.

183   **Conclusion**

184   DCMRL has proven to be a safe technique for imaging the central lymphatic anatomy of patients with

185   primary lymphatic anomalies without any adverse effects that were observed with lipiodol

186   lymphangiography. Increased uptake of this imaging modality will be invaluable in the phenotyping,

187   classification, and management of patients with primary lymphatic anomalies.

188

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291

292

293 **Figures**

294 **Figure 1.** Comparison of non contrast and DCMRL images of the iliac and lumbar lymphatics in a 30-year-old
295 female patient (Case 19) with unilateral right leg lymphoedema. Images shown are over the abdomen and pelvis
296 from the lower lumbar vertebrae to the level of the femoral heads. The lymphatics (white arrows) are faintly
297 visualised on the T_2-weighted non-contrast imaging, with a central slice of the 3D acquisition shown here (1a)
298 and seen much more clearly on the post contrast T_1-weighted imaging, as demonstrated in this MIP SPOILED
299 GRADIENT ECHO image (1b). DCMRL showed normal central lymphatics with good bilateral drainage.

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303 **Figure 2. One of two patients in whom lymphatics were visualised on non-contrast imaging is a** 64-year-
304 old male patient (Case 28) with chylous reflux into right thigh and genitalia, and right thigh and genital
305 lymphoedema. The first image encompasses the lower thorax to the level of the femoral heads. Markedly dilated
306 lymphatics (white arrow) are reasonably well seen on the non-contrast T_2 images, as can be seen in the single
307 central slice of the 3D acquisition shown **(2a) The same dilated lymphatic channel is shown in the post**
308 **contrast image (black arrow) .** Contrast was only injected from left groin as nodes had been surgically
309 removed on the right. However, significant reflux into the right side was identified (white arrow) on post
310 contrast T_1-weighted SPRG image, displayed in MIP form here **(2b).** Dynamic imaging demonstrated the
311 opacification of the right sided channels after injection of contrast from the left.

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314   **Figure 3.** T_2 weighted images of a patient (25-year-old female, Case 8), with enlarged inguinal lymphatic
315   vessels. (3a) shows the MIP resulting from the 2D T_2-weighted TSE sequences, while (3b) is a mid-image slice
316   from this sequence. (3c) and (3d) are the equivalent from the 3D heavily T_2-weighted sequence. Note that while
317   more of the anatomy is visible in a-b, the reduced background signal improves lymphatic vessels and fluid
318   pooling visibility with the 3D acquisition (c-d). Note too that visualisation of lymphatic vessels is rarer in the
319   more moderately 2D T_2-weighted images (a-b) than the 3D (c-d). The arrows highlight lymphatics in the upper
320   thigh on the patient's left.

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338 **Figure 4.** Post contrast T_1 weighted Dixon maximum-intensity projection (MIP) of a 24-year-old male patient
339 (Case 14) with no drainage into normal lymphatic vessels showing superficial rerouting of contrast injected into
340 a right groin lymph node (thick white arrow shows contrast partially extravasated around the right groin lymph
341 node) up the right flank (thin white arrow showing contrast re-routing along right flank).

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349   **Figure 5.** Glue embolization carried out on a patient with reflux (Case 28 from **Figure 2**). Lipiodol
350   lymphangiogram first carried out with injection from left groin lymph node. Refluxing channels targeted
351   fluoroscopically and glue embolization (thin white arrow shows glue cast in embolized lymphatics) carried out
352   after microcatheter (white arrow) catheterisation of the lymphatic vessels.

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356 **Figure 6.** 66-year-old male patient (Case 28) with right leg and genital lymphoedema. Previous surgery with
357 removal of right groin lymph nodes thus only the left was injected. Post contrast maximum-intensity projection
358 (MIP) shows contrast injected from left groin node (black arrow) has refluxed to the right, then rerouting around
359 the right flank (white arrow shows refluxed contrast starting to track up right flank) **(6a).** Delayed imaging
360 showed the contrast from the right flank tracking up the chest wall (white arrow) before draining via further
361 collaterals into the TD (black arrow) **(6b).** Images shown were acquired with the Dixon technique.

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Table 1. Typical imaging parameters for magnetic resonance lymphangiography at 3.0 T. Note that field of view and acquisition matrix varied from participant to participant based on the anatomy. Image acquisition times varied based on the field of view required for adequate anatomical coverage but were generally between 6 – 10 minutes for the heavily T_2-weighted and 0.5-1 minutes per volume for the dynamic T_1-weighted series.

TR: repetition time, TE: echo time, FA: flip angle, NSA: number of signal averages, SENSE factor: SENSitivity Encoding

	TR / TE (ms)	FA (^{0})	Reconstructed Voxel Size (mm)	NSA	Fat Suppression	Motion Reduction	SENSE Factor (Direction)	Typical acquisition time	Features of interest
Pre-contrast:									
Coronal 2D T_2-weighted TSE	'shortest' * / 80 ms	90	0.78 x 0.78 x 4.00	1	SPAIR	Breath-held	2.0 (RL)	5 min	Fluid accumulations (e.g., ascites), anatomy, incidental findings
Coronal 3D heavily T_2-weighted TSE	3200 / 740	90	0.90 x 0.90 x 1.50	2	SPAIR	N/A	1.6 (RL) 1.6 (AP)	9 min	Fluid accumulations, occasionally LV
Coronal 3D T_1-weighted SPOILED GRADIENT ECHO	'shortest' /'shortest' *	30	0.76 x 0.76 x 1.50	1	N/A	N/A	3.0 (RL)	0.5 min	Baseline prior to contrast injection
Post-contrast:									
Coronal 3D T_1-weighted SPOILED GRADIENT ECHO	'shortest' /'shortest' *	30	0.76 x 0.76 x 1.50	1	N/A	N/A	3.0 (RL)	0.5 min / dynamic	Enhancing LV, and contrast leakage/pooling
Coronal 3D T_1-weighted Dixon	4.36 / 1.41/ 2.60 [†]	10	0.71 x 0.71 x 1.00	1	Dixon	N/A	1.6 (RL) 1.6 (AP)	2 min	Enhancing LV, and contrast leakage/pooling

* 'shortest' TR for the Coronal 2D T_2-weighted TSE was approx. 2000ms; 'shortest' TR / TE for the Coronal 3D T_1-weighted spoiled gradient echo were approx. 5 / 2 ms.

† TE_1 = 1.41ms, TE_2 = 2.60ms.

RL: Right – Left; AP: Anterior – Posterior; LV: lymphatic vessels

Table 2. Summary of patients and DCMRL findings

Patient No	Sex	Age at time of study (years)	Lymphatic Diagnosis	Unilateral Injection	Bilateral injection with no uptake	Bilateral injection with bilateral uptake	Bilateral injection with unilateral uptake
1	M	18	WILD syndrome [22]		x		
2	M	38	WILD syndrome		x		
3	M	31	RASopathy (Noonan syndrome)			TD terminates at ligation.	
4	F	39	RASopathy (Noonan syndrome)				Mediastinal, pleural & pericardial leak.
5	F	50	YNS			Normal central lymphatics.	
6	M	61	YNS			Absent TD, collateral filling, LPSA.	
7	F	47	GLD			Dilated lymphatic vessels.	
8	F	25	GLD			Absent TD, collateral filling.	
9	M	46	GLD		x		
10	M	19	GLD	CL severe oedema. CL contrast- reflux.			

11	F	70	GLD			Obstruction with rerouting and filling of distal TD.	
12	M	31	GLD				LPSA, absent lower TD (ligated). Distal filling via collaterals.
13	M	42	GLD	CL severe oedema. Superficial rerouting.			
14	M	24	*ERG*-related GLD [23]				Obstruction with rerouting to TD.
15	F	41	*ERG*-related GLD		x		
16	M	29	SCIDS			Normal central lymphatics.	
17	M	38	Unilateral leg lymphoedema (R)		x		
18	F	16	Unilateral leg lymphoedema (L)				Absent TD, collateral filling.
19	F	30	Unilateral leg lymphoedema (R)			Normal central lymphatics.	
20	F	39	Unilateral leg lymphoedema (L)	CL severe oedema. Normal on side of uptake and centrally.			
21	F	25	Unilateral leg lymphoedema (L)				Normal on side of uptake and centrally.
22	M	29	Left perineal lymphovascular malformation				Normal on side of uptake and centrally.
23	M	33	Left hindquarter lymphovascular malformation, chylous reflux, lymph leakage				Ipsilateral reflux to pelvis and leg.
24	F	52	Bilateral lower limb and abdominal wall lymphoedema, chylous				LPSA, dilated TD with distal TD obstruction.

			ascites & pleural effusions.				
25	M	34	Unilateral leg lymphoedema (L), chylous ascites & pleural effusions			Absent distal TD, LPSA.	
26	M	62	Genital and right leg lymphoedema, chylous reflux, lymph leakage	CL surgery. CL contrast- reflux.			
27	M	17	Genital and bilateral lower limb lymphoedema				Obstruction with rerouting to CC.
28	M	64	Genital and right leg lymphoedema, chylous reflux, lymph leakage	CL surgery. CL contrast- reflux.			

Abbreviation Key

CC - Cisterna chylii

CL - Contralateral

GLD - Generalised Lymphatic Dysplasia

L – left

LPSA - Lymphopseudoaneurysm

R - right

SCIDS - Severe combined immunodeficiency syndrome

TD - Thoracic duct

WILD – Warts, Immunodeficiency, Lymphoedema and anogenital Dysplasia

YNS - Yellow Nail Syndrome

RIGHT
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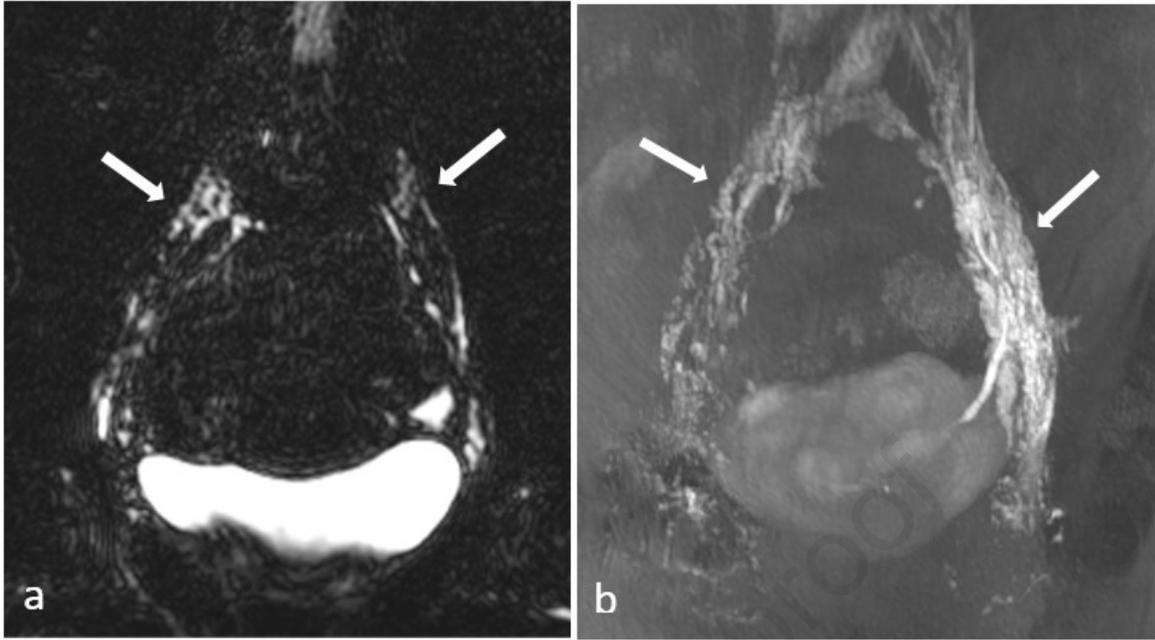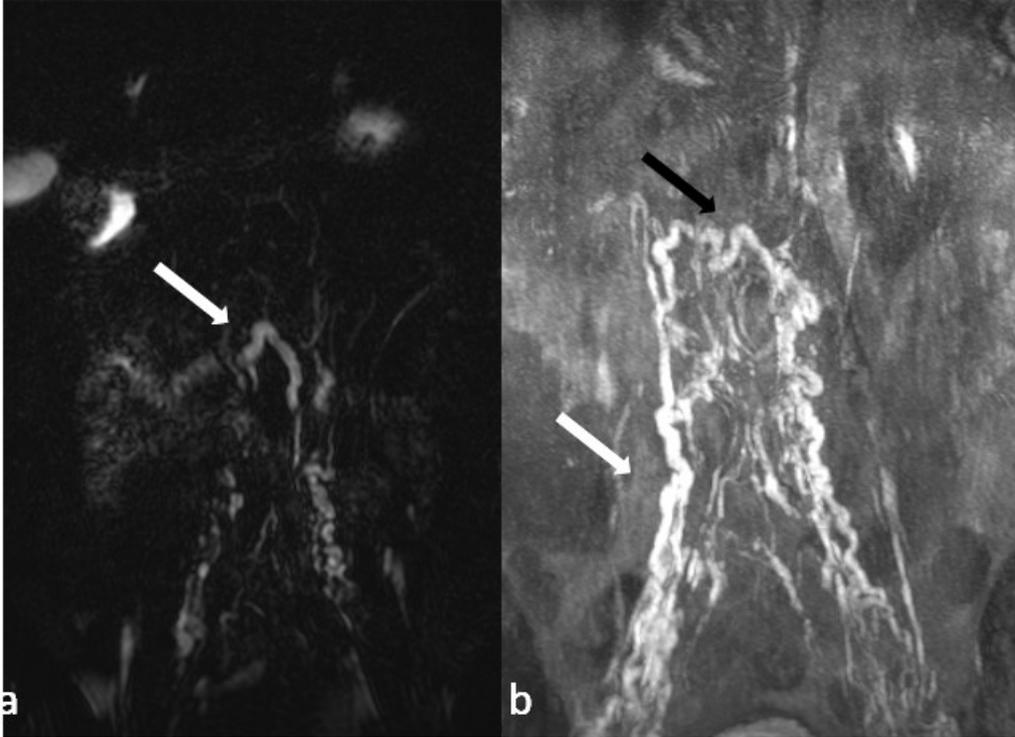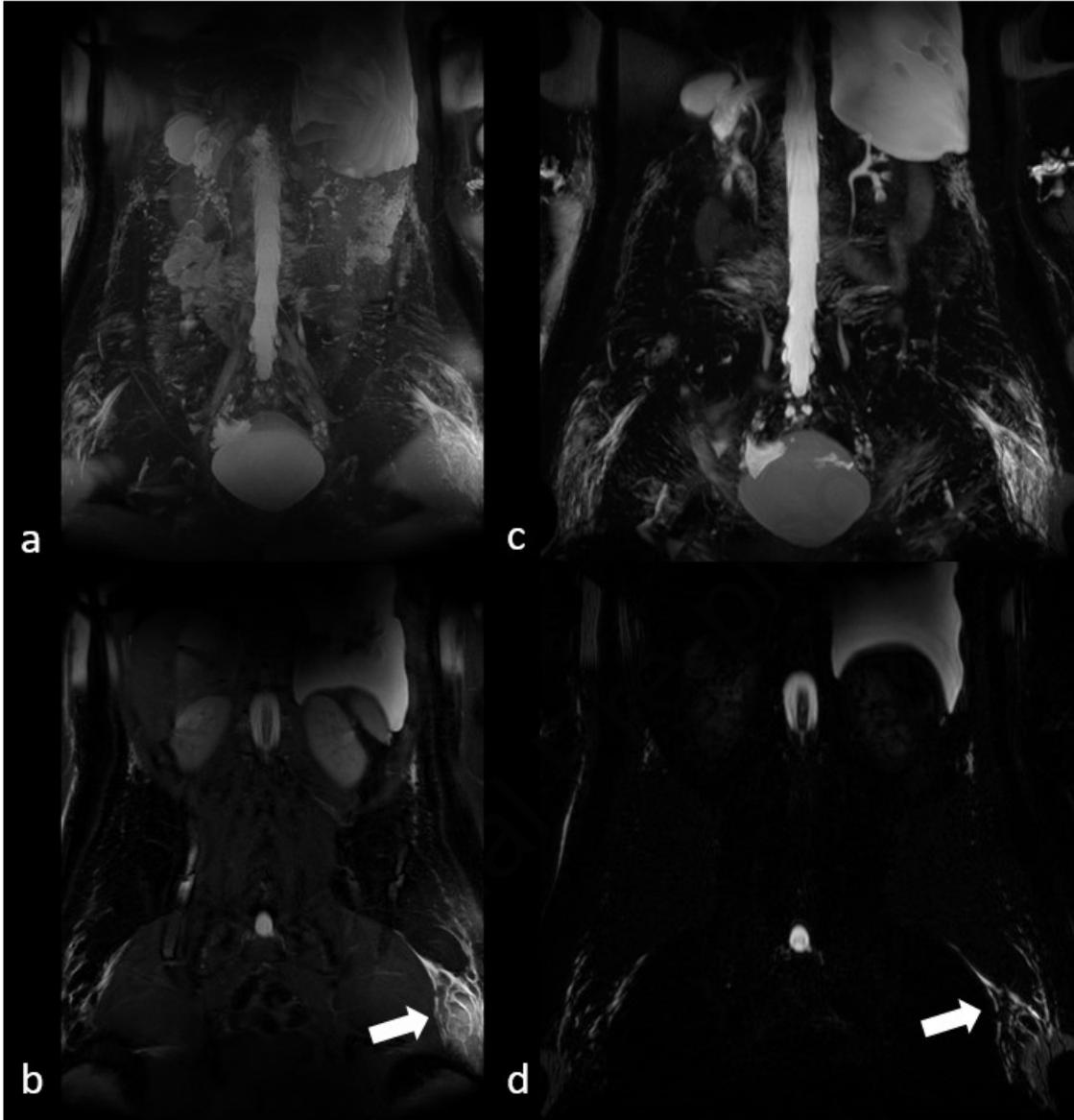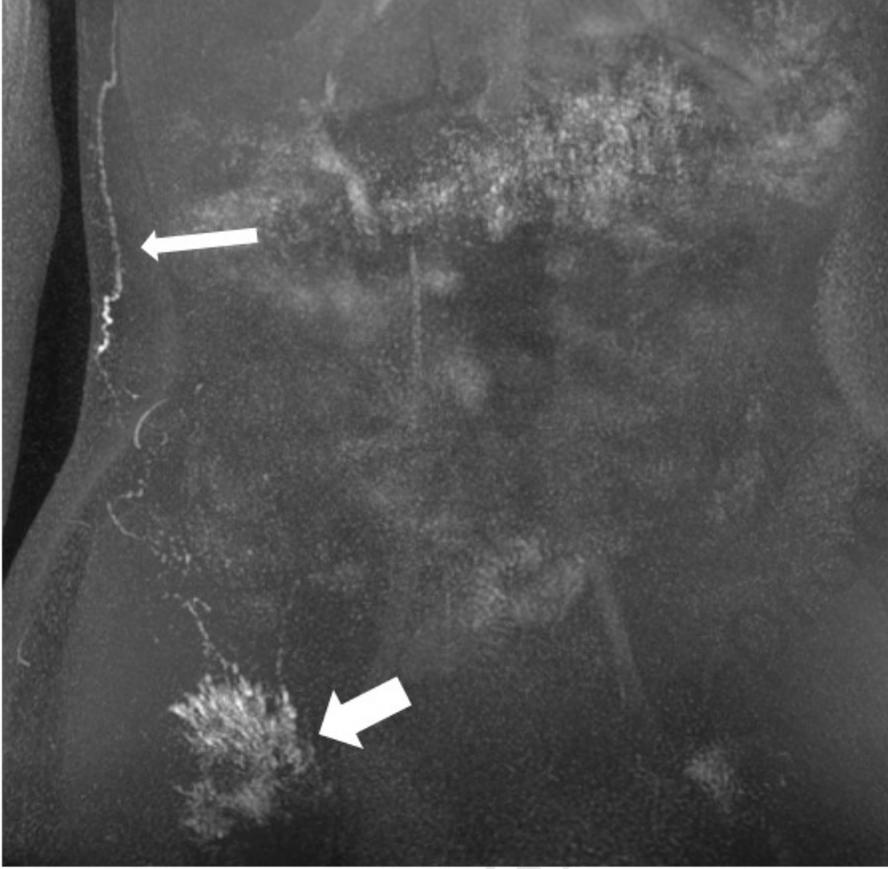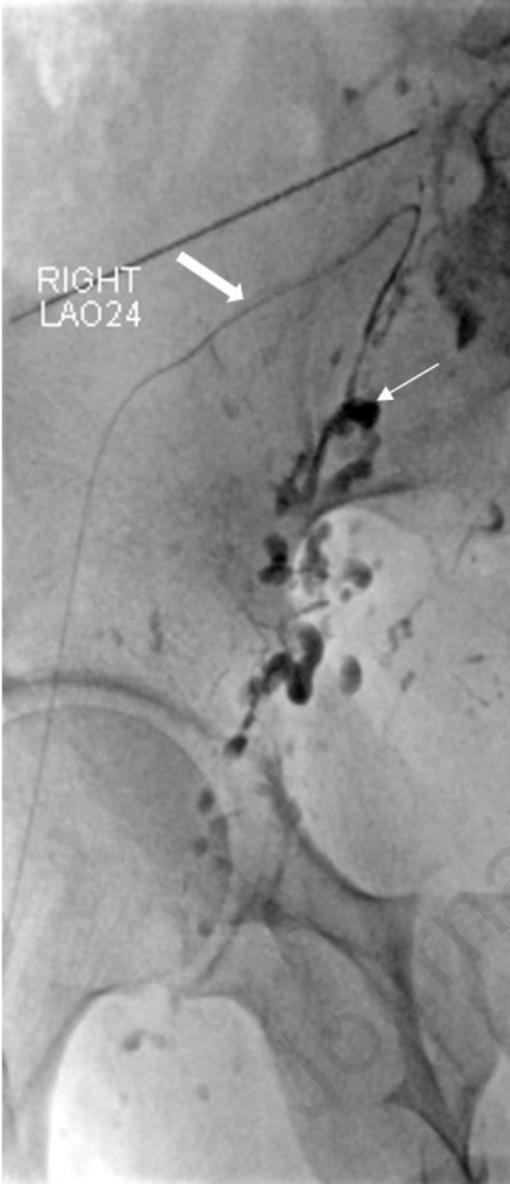
Highlights:

1. Central lymphatics visualised in 82.1% with DCMRL

2. Optimising imaging parameters and needle placement technique are critical

3. DCMRL enables dynamic assessment of central lymphatics with anatomical correlation

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: