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Use of Contrast-Enhanced Ultrasound to Determine Thoracic Duct Patency

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Abstract

The aim of this study was to determine the feasibility of using contrast-enhanced ultrasound (CEUS) evaluation to determine thoracic duct (TD) outlet patency. Nine patients referred for lymphatic imaging and intervention underwent percutaneous intranodal ultrasound contrast injection and conventional lymphangiography (CL). Eight of 9 patients had a patent TD by CEUS and CL. One patient did not have a patent TD. There was 100% agreement between CEUS and CL. These results suggest that CEUS is an imaging modality that might be as accurate as CL in determining TD patency.

Determining thoracic duct (TD) outlet patency is an important branch point in the algorithm for managing patients with lymphatic disorders. Lymphatic flow into the systemic venous system might be limited owing to abnormal lymphatic development, increased central venous pressure, or (acquired) obstruction at the level of the TD outlet. When medical management fails, a patient might be a candidate for lymphatic procedures, such as innominate vein rerouting, or a lymphovenous anastomosis to enhance lymphatic flow (1–4). However, the strategy employed is dependent not only on the underlying diagnosis but also on the patency of the TD outlet.

Several advances in lymphatic imaging techniques have improved visualization of anatomy and flow. Pedal lymphangiography and pedal lymphoscintigraphy, which were among the

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Video 1 can be found by accessing the online version of this article on www.jvir.org and clicking on the Supplemental Material tab.

first imaging modalities, were time-consuming, challenging, and limited in their ability to visualize central lymphatic flow (5–7). Intranodal lymphangiography has now emerged as an imaging technique to visualize the central lymphatic system because it allows bypassing of the lower extremities (8). The development of intranodal dynamic contrast-enhanced magnetic resonance lymphangiography (DCMRL) has allowed for improved spatial and temporal resolution (9–11) and is rapidly being adopted as a minimally invasive method to access central lymphatic anatomy and flow. However, there are still cases where the TD outlet patency is uncertain and the use of conventional lymphangiography (CL) is necessary.

CL, which is the gold standard, is still time-consuming, might involve a long anesthetic time, and involves radiation exposure (7,12). Previously, high-resolution ultrasound has been used to determine the patency of the TD outlet in healthy adults, but there has been limited experience using this technique to interrogate the TD outlet in children with suspected lymphatic disorders (13). Thus, the purpose of this study was to determine whether contrast-enhanced ultrasound (CEUS) could be used to assess TD patency after percutaneous intranodal ultrasound contrast injection.

MATERIALS AND METHODS

Patient Selection

The institutional review board at the study center approved this retrospective study of consecutive patients who presented for clinically indicated lymphatic imaging and intervention between November 1, 2017, and September 30, 2018. All patients who underwent DCMRL as part of planning for lymphatic intervention were eligible to undergo CEUS. There were 9 patients (7 males) with a mean age of 3.5 years (range, 4 months to 13.8 years) (Table 1). Seven of nine (78%) had chylothorax, 1 had protein-losing enteropathy, 1 had anasarca, and 1 had plastic bronchitis. Also, 78% (7/9) had congenital heart disease, and 1 had cardiomyopathy. Descriptive statistics were used to report patient demographics. All patients had clinical evidence of lymphatic dysfunction.

Imaging Technique

Imaging was performed in an XMR suite that combines a magnetic resonance imaging scanner with a cardiac catheterization laboratory. Patients first underwent DCMRL, which has been previously described (9). Briefly, bilateral inguinal lymph nodes (1 on each side) were accessed in the catheterization lab under ultrasound guidance using a 25-gauge spinal needle. A small amount of water-soluble iodinated contrast agent was injected to confirm positioning of the needle in the lymph node by fluoroscopy. The needle was then secured in place with Tegaderm (3M, Maplewood, Minnesota). DCMRL was then undertaken using a gadolinium dose of 0.2 mmol/kg diluted 1:1 with normal saline injected at a rate of 0.5–1.0 ml/minute.

After DCMRL completion, the patient was returned to the catheterization lab. To perform ultrasound imaging, the patient was in the supine position with the neck slightly extended. The left (or right) internal jugular vein was first visualized just above the clavicle at an oblique angle; an L12 probe was then rotated rightward (or leftward) parallel to the clavicle.

The TD was visualized draining into the left (or right) venous angle or in one of the internal or subclavian veins. Using the inguinal needles, 3 ml of contrast (sulfur hexafluoride lipid-type A microspheres; Bracco Diagnostics Inc, Monroe Township, New Jersey) was delivered over 20–30 seconds followed by 3 ml of normal saline. Ultrasound imaging (Epiq; Philips, Amsterdam, Netherlands) of the left or right neck was initiated at the time of contrast injection and continued between 3 and 5 minutes or until contrast appeared. If it was deemed that an intervention was appropriate, the patient then underwent CL.

A cardiologist with specialized lymphatic interventional training performed the CEUS. The cardiologist and an interventional cardiologist with over 9 years of experience performed the lymphangiography. Two blinded and independent pediatric radiologists with over 5 years of experience in lymphatic and CEUS imaging reviewed the data to evaluate TD patency. TD patency was determined by visualization of lymphatic contrast passing into the venous system in the left or right neck. Results were correlated with DCMRL and CL. The DCMRL was interpreted separately by 1 of the blinded radiologists. Neither radiologist performed the procedures.

RESULTS

Of the 9 cases, the contrast was seen entering the vein through the TD outlet in 8 cases and was therefore classified as patent (Fig 1a,b and Video 1 [available online on the article's Supplemental Material page at www.jvir.org]). In 1 case, no contrast was seen entering the venous system and was therefore classified as not patent (Fig 2a). There was agreement between both CEUS readers on all cases. DCMRL was performed in all patients (Table 2). The TD was visualized by DCMRL in all cases, but the TD outlet could not be directly visualized to assess patency (Fig 1c). The TD was noted to be moderately dilated in 3 cases. The TD was mildly tortuous in 5 cases and moderately tortuous in 4 cases All patients were assessed for the presence of contrast reflux into the neck lymphatics, and only 1 of 9 patients had significant reflux; this patient had a patent TD. In none of the patients could patency of the TD be determined by DCMRL. All patients also had conventional lymphangiography. Of these cases, the TD outlet was patent in 8 of 9 by CL (Fig 2b). There was 100% agreement between the findings on CEUS and CL.

DISCUSSION

Over the last several years, advances in imaging of the lymphatic system have led to improvements in efficiency of data acquisition and diagnostic accuracy. Specifically, DCMRL has enabled gathering of detailed information regarding anatomy and central lymphatic flow that has aided in determining which interventional technique is most appropriate for the patient (2,7,9). However, assessing patency of the TD on DCMRL is challenging, as the TD outlet cannot be directly visualized. There are secondary signs that the TD might be patent, such as a small duct with normal caliber, and secondary signs that it is not patent, such as a large duct with multiple collateral channels. The temporal resolution of DCMRL is another limitation, as it does not allow for direct visualization of gadolinium entering the venous system—a task that is made more challenging by rapid dilution of gadolinium in the venous system. Although the patient's underlying diagnosis and anatomy is critical in defining the best strategy (embolization, lymphovenous anastomosis, or innominate vein rerouting), it is imperative to determine patency before considering advanced methods of decompression.

This study demonstrates that CEUS may be used as a method to identify TD patency. CL is currently the gold standard; however, it requires patients to undergo a prolonged anesthetic procedure and more radiation. Other limitations to CL include the increased risk of bleeding and infection, especially when transabdominal access is necessary to demonstrate the TD. Furthermore, the use of Lipiodol is problematic in certain populations, including those with right to left shunting, which can lead to strokes or central lymphatic flow disorders, as they do not tolerate embolization/sclerosis that can be induced by Lipiodol injection (14,15).

Ultrasound imaging of the TD in adults has been previously described. In a study by Seeger et al (13) of 585 patients, ultrasound imaging was able to assess the anatomy and function of the TD in 96% of cases. The use of contrast in a small subset of patients with liver cirrhosis was used to demonstrate differentiation between the TD and the surrounding vessels.

The work currently presented suggests that CEUS might similarly be used in children to assess TD patency. It offers an imaging modality with less radiation and shorter anesthetic time and might provide a less invasive and faster method of identifying function. At the authors' institution, CEUS is frequently performed after DCMRL, as this modality rarely demonstrates outlet patency. Lymphangiography is performed if the diagnosis and findings on imaging suggest that an intervention is possible.

This retrospective study had limitations owing to a small sample population and procedures being performed at a single center. Furthermore, there were few patients who had TDs that were not patent, and thus the specificity of CEUS to determine TD patency is limited. Another consideration is that, in the setting of an obstructed TD, small collaterals might form that allow contrast to enter the vein. To mitigate this, the largest connection of the TD to the vein was identified via ultrasound. Another limitation was that not all patients had CL. Wider use of CEUS might lead to further assessment of this technique.

In conclusion, this exploratory study suggests that CEUS might be a less invasive method of assessing TD outlet patency either as a standalone technique or in conjunction with DCMRL. Further investigations are needed, but it might provide an opportunity to eliminate the need of CL in cases where no percutaneous intervention is needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ABBREVIATIONS

CEUS	contrast-enhanced ultrasound
CL	conventional lymphangiography
DCMRL	dynamic contrast-enhanced magnetic resonance lymphangiography

TD	thoracic duct

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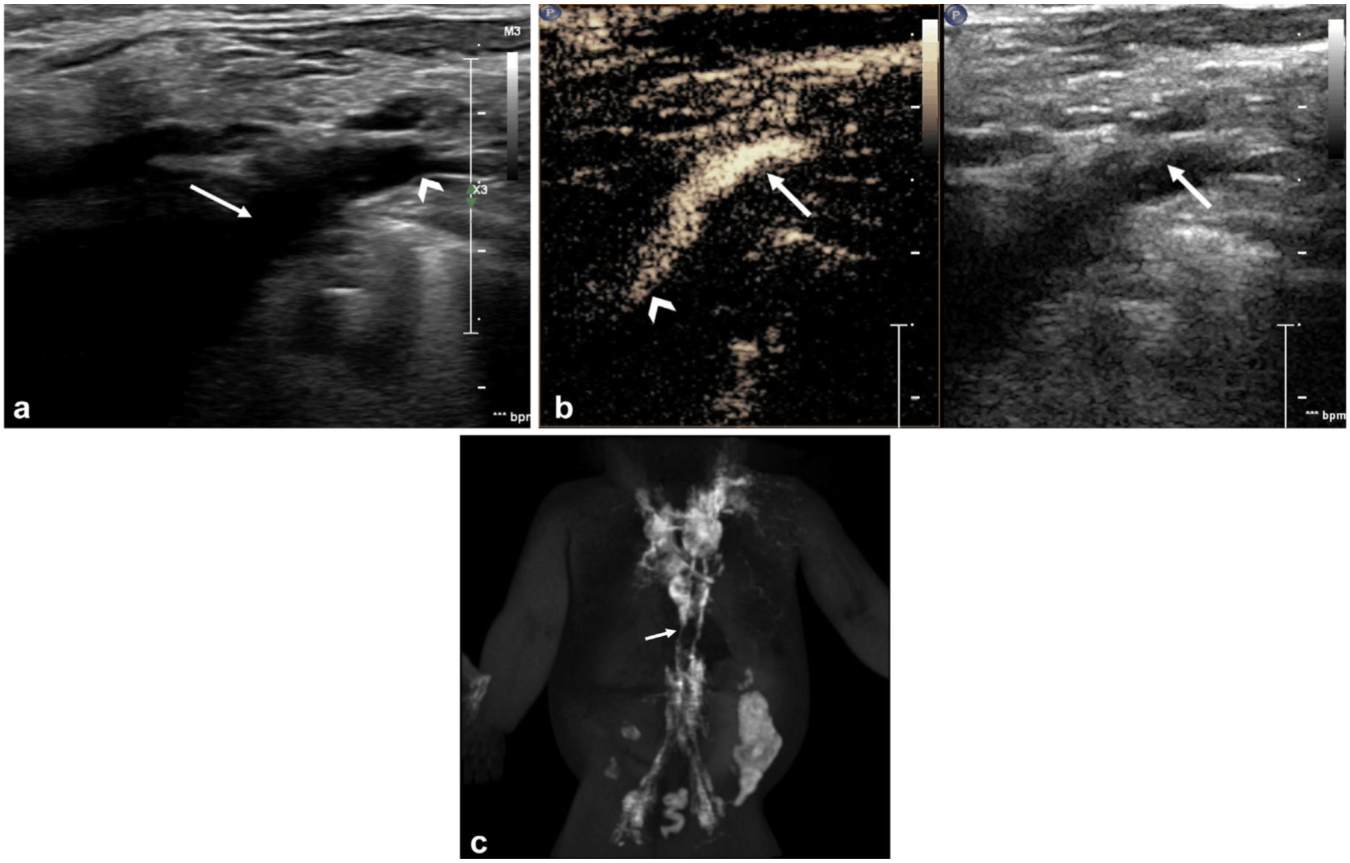

Figure 1.

(**a**) Two-dimensional ultrasound of the left internal jugular vein (arrowhead) and proximal innominate vein (arrow) before contrast injection. (**b**) CEUS of the left neck reveals passage of contrast injected into the lymphatic system into the left internal jugular vein (arrow) extending into the innominate vein (arrowhead), confirming patency of the TD outlet. (**c**) Magnetic resonance lymphography in the same patient as in Figure 1a, demonstrating the TD (arrow) and lymphatic network. Because of the complex and abnormal network, it is not possible to determine patency of the TD.

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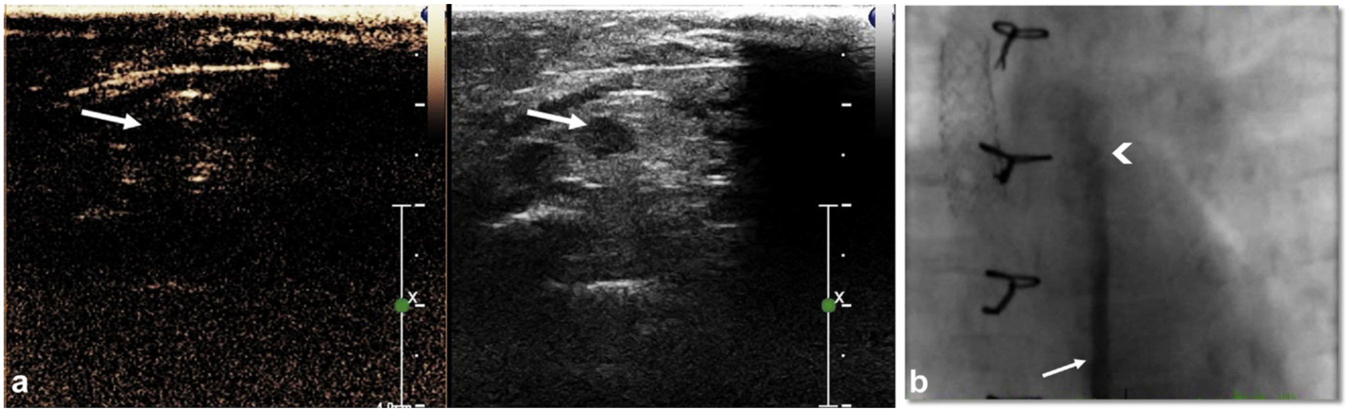

Figure 2.

(**a**) CEUS of the left neck in this patient reveals lack of passage of contrast into the internal jugular vein (arrows) after injection into the lymphatic system. (**b**) CL of the TD (arrow) in the same patient as in Figure 2a with no venous connection (arrowhead), consistent with occluded TD outlet.

Table 1.

Patient Characteristics

	Age (y)	Sex	Diagnosis	Lymphatic diagnosis	Surgical history
1	6.7	M	Ebstein anomaly, PA	Chylothorax	Fenestrated Fontan
2	5.7	M	HLHS	Chylothorax	Fenestrated Fontan
3	3.6	M	TGA, PA	Chylothorax	Heart transplant
4	14.6	M	Tricuspid atresia, PA	PLE	Fenestrated Fontan
5	13.7	F	Aortic atresia	Plastic bronchitis	Fenestrated Fontan
6	0.5	M	TGA	Chylothorax	ASO
7	0.4	F	PDA	Anasarca	PDA occlusion
8	0.4	M	No CHD/idiopathic	Chylous ascites	None
9	0.5	M	No CHD/idiopathic	Chylothorax	None

ASO = arterial switch; CHD = congenital heart disease; HLHS = hypoplastic left heart syndrome; PA = pulmonary atresia; PDA = patent ductus arteriosus; PLE = protein-losing enteropathy; TGA = transposition of the great arteries.

Table 2.

Imaging Findings

Patient	Dynamic contrast MR lymphangiography			Conventional lymphangiography		Contrast-enhanced ultrasound
	Findings	**Reflux into neck lymphatics**	**TD seen**	**CL findings**	**TD patent**	**TD patent**
1	Moderately dilated and tortuous TD	Severe	Y	Severely dilated TD	Y	Y
2	Mildly dilated and moderately tortuous TD	Moderate	Y	Dilated and tortuous TD	Y	Y
3	Mildly dilated and tortuous TD	Mild	Y	Dilated and tortuous TD	Y	Y
4	Moderately dilated TD	Mild	Y	Mildly dilated TD	Y	Y
5	Mildly dilated and tortuous TD	Moderate	Y	Massively dilated and tortuous TD	Y	Y
6	Mildly dilated and moderately tortuous TD	Mild	Y	Dilated and tortuous TD	N	N
7	Mildly tortuous TD	Mild	Y	No significant dilation or tortuosity of TD.	Y	Y
8	Mildly tortuous TD	None	Y	No significant dilation or tortuosity of TD.	Y	Y
9	Moderately dilated and tortuous TD	None	Y	No significant dilation or tortuosity of TD.	Y	Y

NA = not applicable, as study was not performed or patency was unable to be assessed via the imaging modality; TD = thoracic duct.