LYMPHATIC DISEASES IN INTERVENTIONAL RADIOLOGY – breaking the toughest tortoise shell

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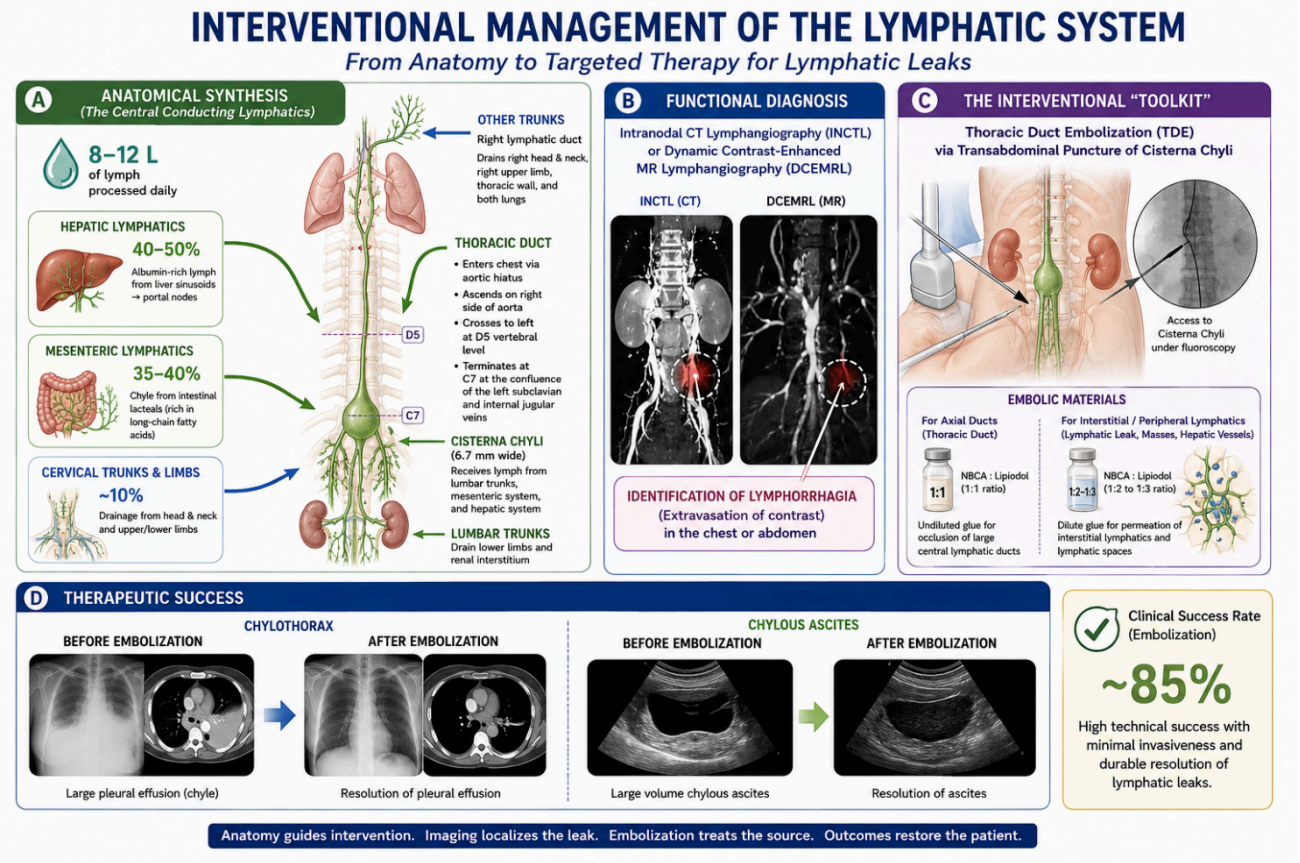
***Abstract*—Interventional Management of Lymphatic Disorders**

Lymphatic abnormalities range from isolated malformations to complex system-wide abnormalities and lymphedema. The Central Conducting Lymphatics (CCL), comprised of the lumbar trunks, cisterna chyli, and thoracic duct, handle a daily flow of 8–12 L of interstitial fluid, with significant contributions from hepatic (50%) and mesenteric (40%) sources. Diagnosis is facilitated by functional imaging, such as Intranodal Dynamic Contrast-Enhanced MR Lymphangiography (DCEMRL) and the more rapid Intranodal CT Lymphangiography (INCTL). Management strategies are categorized by the SEOAS system (Symptoms, Etiology, Origin, Anatomy, Syndromic), utilizing sclerotherapy or embolization (e.g., Thoracic Duct Embolization) to treat leaks such as chylothorax, chylous ascites, and lymphoceles.



I. Introduction

The field of **interventional radiology (IR)** has evolved to offer specialized solutions for **complex lymphatic abnormalities** and advanced oncological treatments through **precision ablation technologies**. Lymphatic disorders are currently categorized using the **ISSVA 2025** classification—distinguishing between isolated malformations, complex systemic abnormalities, and lymphedema—and the **SEOAS system**, which guides interventional management based on symptoms, etiology, and anatomical location. Clinical success in treating these conditions, such as chylothorax or lymphoceles, necessitates an intricate knowledge of the **Central Conducting Lymphatics (CCL)** and its primary components, including the **cisterna chyli** and the **thoracic duct**. Diagnostic precision in this domain has been significantly enhanced by functional imaging techniques like **Dynamic Contrast-Enhanced MR Lymphangiography (DCEMRL)** and the rapid **Intranodal CT Lymphangiography (INCTL)**.

II. Anatomy and Flow Dynamics

The anatomy and flow dynamics of the lymphatic system are centered on a complex network of vessels and nodes that process approximately **8–12 L of interstitial fluid daily**, with roughly 4 L being shunted back into the venous system at the lymph node level.

The Lymphatic Network and Checkpoints

The system begins with smaller **afferent lymphatic vessels** that lead into collective ducts. These vessels pass through **lymph nodes (LN)**, which serve as solid checkpoints; there are approximately **450 lymph nodes** distributed throughout the body. From these nodes, **efferent ducts** carry the lymph into the **Central Conducting Lymphatics (CCL)**.

Central Conducting Lymphatics (CCL) Axial Structures

The CCL is composed of three primary axial structures: the **lumbar trunks**, the **cisterna chyli**, and the **thoracic duct** (Figure 1).

- **Cisterna Chyli:** This is the largest lymphatic structure in the body, measuring approximately **6.7 mm across** and **10–20 mm in craniocaudal length**. It acts as a central reservoir, receiving lymph from the lower limbs (via lumbar trunks), the mesenteric system, and the hepatic system.
- **Thoracic Duct:** Originating from the cisterna chyli, it enters the chest through the **aortic hiatus** and courses posterior to the esophagus. It stays to the right of the aorta until it **crosses to the left at the D5 vertebral level**. It then passes behind the left common carotid artery (CCA) and turns downward at the C7 level to join the venous system at the confluence of the **subclavian vein (SCV) and internal jugular vein (IJV)**. It contains distal valves designed to prevent the reflux of venous blood into the lymphatic system.
- **Right Lymphatic Duct:** This is a separate drainage pathway that specifically services the **right head and neck, the upper limbs, the thoracic wall, and both lungs**.

Anatomical variants of the thoracic lymphatics is shown in figure 2. 95% of the time the drainage occurs into the left subclavian vein. The surgical/interventional impact of these variations are presented in table 1.

Table 1: Surgical and interventional implications of the variants in thoracic duct

Anatomical Variant	Pathophysiology & Location	Clinical Significance	Risk Assessment
Mediastinal Plexus	Multiple small conduits replacing a single thoracic duct.	Incredibly difficult to identify/isolate during thoracoscopy.	High risk of Post-Op Chylothorax
Aberrant Right Termination	Duct empties into right internal jugular or subclavian vein.	Vulnerable during standard right-sided neck dissections.	Iatrogenic Chyle Leak
Bifid Lower Duct System	Failure of embryonic left and right trunks to fuse.	If only one trunk is clipped or ligated, leakage continues.	Incomplete Surgical Ligation
Left-Sided Cisterna Chyli	Cisterna chyli originates on the left of the abdominal aorta.	Displaced landmark alters retroperitoneal approach.	Accidental Vascular Injury

Flow Contributions and Fluid Characteristics

The contents of the cisterna chyli are determined by the specific organs they drain, which also dictates the biochemical makeup of the lymph. The normal volume of lymph is contributed mainly by hepatic and mesenteric lymphatics (Table 2).

Table 2: Contribution of lymphatic circulation volume by organ

Source	Volume Contribution	Key Characteristics
Hepatic Lymphatics	**~40–50%**	Highly rich in **albumin (90%)**; drains from the sinusoids through periportal lymphatics and portal nodes.
Mesenteric Lymphatics	**~35–40%**	Rich in **long-chain fatty acids and chylomicrons**; collected by **lacteals** in the intestinal wall (primarily the ileum), creating a milky fluid known as chyle.
Lungs	**5–15%**	Standard drainage of the pulmonary parenchyma.
Limbs & Cervical Trunks	**~10%**	Characterized by **low levels of both albumin and triglycerides**.
Kidneys	**5–10%**	Drains the renal interstitium into the lumbar trunks.

The origin of **chylous ascites** is typically traced to the mesenteric lymphatics or the cisterna chyli following the drainage of mesenteric efferents. Conversely, **hepatic lymphorrhea** (often seen after liver surgery) presents as a clear fluid due to its high albumin and low triglyceride content. A compendium of anatomy and physiology is presented in figure 3.

III. Clinical Presentations and Imaging Diagnosis

Clinically, presentation and imaging of lymphatic diseases are categorized by anatomical site, fluid characteristics, and specific functional imaging techniques.

Clinical Presentation

Clinical manifestations vary significantly depending on the site of the lymphatic leak or abnormality:

- **Chest:** Often occurring after thoracic, neck, or esophageal surgery, it presents as **chylothorax**. This accumulation is often accentuated by negative pleural pressure.
- **Abdomen:** Typically follows retroperitoneal dissection or radiation, presenting as **chylous ascites** or parietal soft tissue edema.
- **Liver Hilum:** Following liver or porta hepatis surgery, this presents as **hepatic lymphorrhea**. Notably, this is a **clear fluid** due to its high albumin and low triglyceride content.
- **Pelvis and Groin:** Usually resulting from node dissection or catheter access, it presents as a **lymphocele**, which can extend from the extra-peritoneal pelvis to the scrotum.
- **Systemic Symptoms:** Under the **SEOAS system**, clinicians also classify presentations by whether they are **traumatic** (e.g., post-surgical) or **non-traumatic**, and whether they involve a specific syndrome like Gorham-Stout or Noonan syndrome.

A precis is presented in table 3.

Table 3: Identification of Lymphorrhagia Sites

Site	Predisposing Condition	Presentation
Chest	Thoracic, neck, or esophageal surgery	**Chylothorax** (negative pleural pressure accentuates accumulation).
Abdomen	Retroperitoneal dissection (RPLND) or radiation	**Chylous ascites** or parietal soft tissue edema.
Liver Hilum	Porta hepatis or liver surgery	**Hepatic lymphorrhea** (presents as clear fluid).
Pelvis/Groin	Node dissection or catheter access	**Lymphocele** (extra-peritoneal pelvis to scrotum).

Imaging Diagnosis

Diagnostic precision has been enhanced by functional imaging modalities that help identify the exact site and nature of the lymphatic disorder:

- **Intranodal Dynamic Contrast-Enhanced MR Lymphangiography (DCEMRL):** This is considered superior for **functional imaging**. It is specifically used to identify extravasation, reflux, and dermal backflow.
- **Intranodal CT Lymphangiography (INCTL):** A rapid diagnostic tool (taking only 5–15 minutes) that uses iodinated contrast to identify the **cisterna chyli** and the confluence of the thoracic duct.
- **Indocyanine Green (ICG) Lymphangiography:** This modality is best suited for visualizing **smaller superficial lymphatics** and is frequently used during surgical lymphvenous anastomosis.

The integration of these imaging techniques allows for a precise determination of the **origin of the fluid**—whether it is chylous (milky fluid from mesenteric sources), non-chylous, or hepatic—which is critical for guiding interventional management.

A precis is presented in table 4.

Table 4: Imaging Modalities

Modality	Description/Usage
DCEMRL	Superior for functional imaging; identifies extravasation, reflux, and dermal backflow.
INCTL	Fast (5–15 mins); uses iodinated contrast to identify the cisterna chyli and duct confluence.
ICG Lymphangiography	Best for smaller superficial lymphatics; used for surgical lymphvenous anastomosis.

IV. Classification of Lymphatic Disorders

The updated ISSVA (2025) has tweaked the erstwhile classification. The following table deals with the sub-classifications (Table 5). The SEOAS system classifies lymphatic malformations by theie categorical management (Table 6).

V. ISSVA Classification (2025)

This updated system distinguishes between isolated malformations, complex systemic abnormalities, and lymphedema:

- **Isolated:** Includes **lymphatic malformations** (which can be microcystic, macrocystic, or mixed) and **angiokeratoma**.
- **Complex:** This category encompasses systemic conditions such as **Generalized Lymphatic Malformation (GLA)**, **Kaposiform Lymphangiomatosis (KLA)**, **Gorham-Stout** disease, **Central Conducting Lymphatic Abnormality (CCLA)**, and **Generalized Lymphatic Dysplasia**.
- **Lymphedema:** Divided into **Primary** (further sub-classified as congenital, precox/Meige's, or tarda) and **Secondary**.

Table 5: ISSVA Classification (2025)

Category	Types
Isolated	Lymphatic malformations (microcystic, macrocystic, mixed) and angiokeratoma.
Complex	Generalized Lymphatic Malformation (GLA), Kaposiform Lymphangiomatosis (KLA), Gorham-Stout, Central Conducting Lymphatic Abnormality (CCLA), and Generalized Lymphatic Dysplasia.
Lymphedema	Primary (congenital, precox/Meige's, tarda) and Secondary.

VI. SEOAS System for Interventional Management

The SEOAS system is a categorical framework used by interventionalists to determine the most appropriate treatment strategy (such as sclerotherapy or embolization) based on five key parameters (Table 6).

Table 6: SEOAS system

Parameter	Classification Options
Symptoms	Lymphatic lymphorrhea or lymphedema.
Etiology	**Traumatic** (e.g., post-surgical) or **Non-traumatic**.
Origin of Fluid	**Chylous** (milky, mesenteric origin), **non-chylous**, or **hepatic** (clear, high albumin).
Anatomical Location	Specific site of the issue, such as **chylothorax**, **chylous ascites**, **chyluria**, or **cutaneous lymphorrhea**.
Syndromic	Associated syndromes including **Gorham**, **Noonan**, **GLA**, **KLA**, or **Lymphangioleiomyomatosis**.

By applying these classifications, clinicians can better understand the pathophysiology of a patient's condition and select the intervention with the highest success rate, such as **Thoracic Duct Embolization (TDE)**, which currently shows a clinical success rate of approximately 85%.

VII. Management Strategies

- **Embolization:** Used for recalcitrant cases (to medical therapy). Embolisation includes **thoracic Duct Embolization (TDE, using 1:1 glue or coils)** or **interstitial lymphatic embolization** (dilute 1:2 to 1:3 glue) for visceral lymphatics or **intranodal lymphatic embolization** for lymphoceles or small leaks (axillary or inguinal node access).
- **Sclerotherapy:** Involves draining the collection and dwelling a sclerosant (1/3 to 1/2 volume) for 2 hours.
- **Success Rates:** Embolization demonstrates higher clinical success (~85%) compared to sclerotherapy (~65%).

A simplified flow diagram from diagnosis to treatment is presented in figure 4.

Table 7 differentiates **Inguinal Lymph Node (LN) Embolization**, **Hepatic Lymphatic Embolization**, and **Thoracic Duct Embolization (TDE)** based on the provided sources and supplemental clinical knowledge where specified.

Table 7: Comparison of Lymphatic Embolization Techniques

Feature	Inguinal LN Embolization	Hepatic Lymphatic Embolization	Thoracic Duct Embolization (TDE)
Primary Indications	**Groin lymphoceles** or **inguinal lymphorrhea** following catheter access (e.g., ECMO) or pelvic surgery (renal transplant, vascular surgery).	**Hepatic lymphorrhea** (post-liver/porta surgery) and **Protein Losing Enteropathy (PLE)**.	**Chylothorax** (post-surgical or traumatic), plastic bronchitis, and chylous ascites.

Anatomical Target	**Upstream lymphatic trunks** or site of discontinuity leading to a lymphocele.	**Dilated periportal lymphatics** or hepatoduodenal channels.	**Cisterna Chyli** and the **Thoracic Duct** axial structures.
Access Route	Direct puncture of an **inguinal, axillary or pelvic lymph node** under fluoro, CT, or US guidance.	**Percutaneous transhepatic access** (similar to PBD) or endoscopic duodenal access.	**Transabdominal access** to the Cisterna Chyli following Intranodal Lymphangiography (INL).
Embolic Materials	**Dilute glue (1:2 to 1:3)** or ethiodized oil (Ethiodol).	**Dilute glue (1:2 to 1:3)**; requires forceful injection due to small needle size.	**Coils** or **1:1 Glue** (minimal dilution) often used with a Dextrose 5% buffer to prevent reflux.
Visual Appearance of Leak	Usually visible via INL; may require retrograde access if the leak is not apparent.	Often presents as **clear fluid**; visually appears as **periportal hypoechoic areas** on US.	**"Milky" chyle** accumulation (chylothorax); visualized via INL of inguinal/pedal nodes.
Key Challenges / "Tricks"	Steeper learning curve for intra-nodal access compared to sclerotherapy.	Maintaining **needle stability** during forceful glue injection is difficult.	**CC access** may involve traversal of the aorta, colon, or gallbladder (best avoided).
Reported Success	Approximately **85% clinical success** (superior to sclerotherapy's 65%).	*Not explicitly cited*, but noted as effective for central liver lesions.	**90–95% success** if CC access and catheterization are successful.

Technical Insights and Clinical Context

- **Inguinal LN Embolization:** This procedure is preferred for **uncontained lymphoceles** or those recalcitrant to sclerotherapy. A specific technique involves an **INL to identify the site**, followed by a **D5 flush** to clear Ethiodol before injecting the dilute glue.
- **Hepatic Lymphatic Embolization:** This is uniquely indicated for **non-chylous (clear) lymphorrhea**. Because hepatic lymph makes up approximately **50% of the volume** in the cisterna chyli and has a very high (90%) albumin content, leaks here can quickly lead to significant protein loss.
- **Thoracic Duct Embolization (TDE):** TDE is considered the definitive interventional treatment for **chylothorax**. To prevent glue from entering the Subclavian Vein (SCV) due to slow flow, practitioners may use a **two-wire technique** to place a second microcatheter for **Dextrose 5% infusion**, which acts as a buffer for the glue.
- **Common Technical Adjuvants (Internet Insight):** While not explicitly in the text for all three, the use of **Indocyanine Green (ICG)** is increasingly used for real-time visualization in both inguinal and hepatic settings, particularly if surgical lymphovenous anastomosis is being considered as an alternative.
- **Techniques to Hasten Lipiodol:** These include pneumatic compression of calves, saline flushes, and **heating up the Lipiodol** (a technique credited to **Dr. Ajit Yadav**).

VIII. Figures

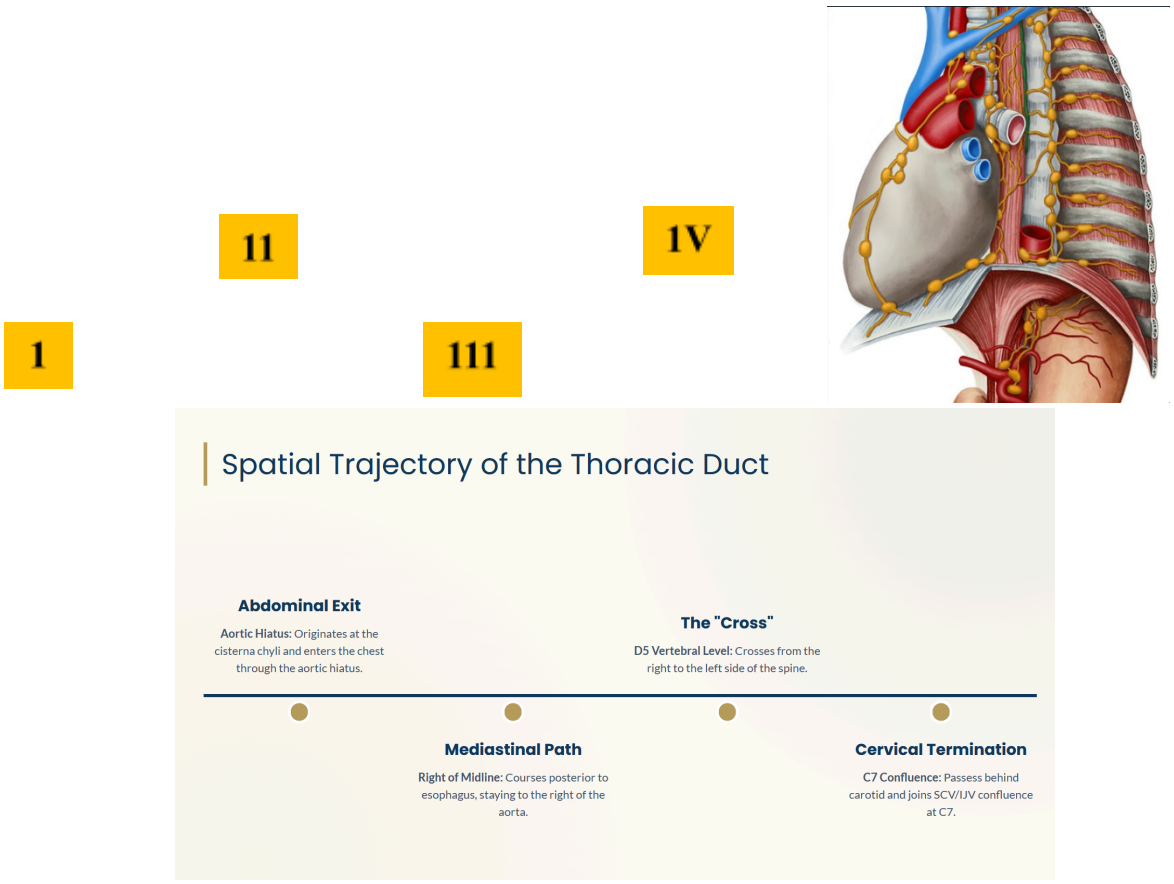


Figure 1: Trajectory of the thoracic duct.

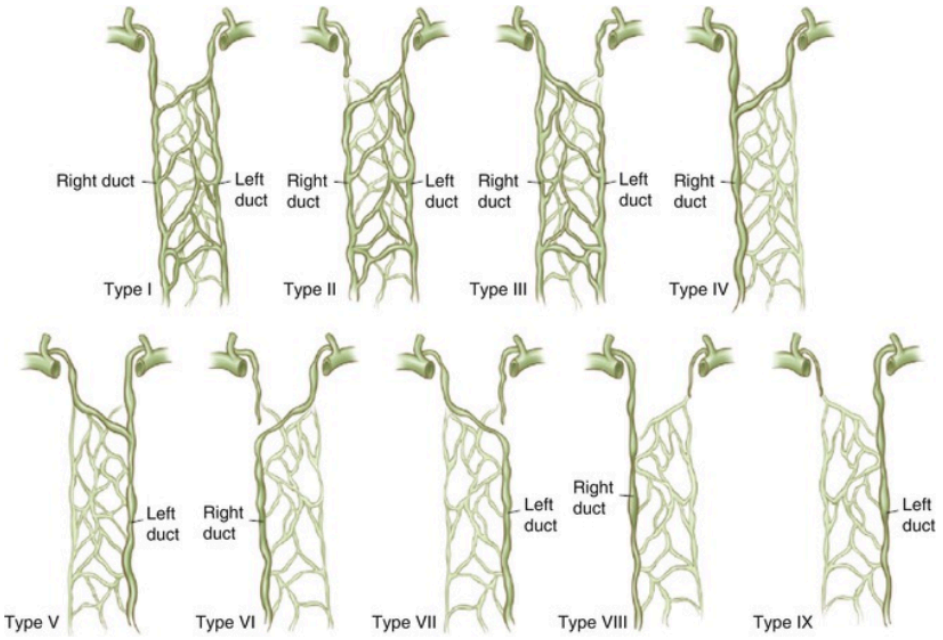


Figure 2: Thoracic duct drainage variants.

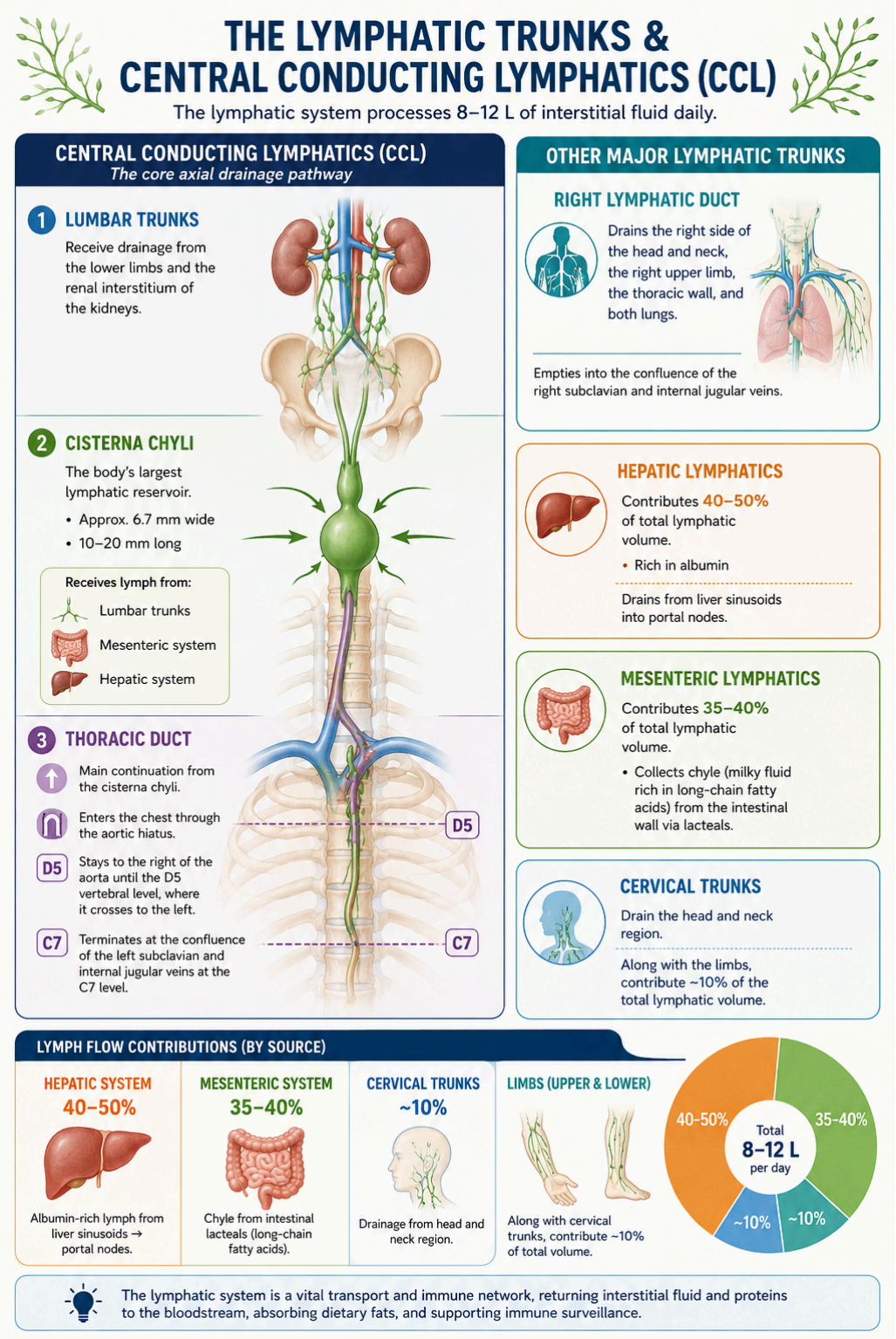


Figure 3: Overall lymphatic anatomy and flow characteristic.

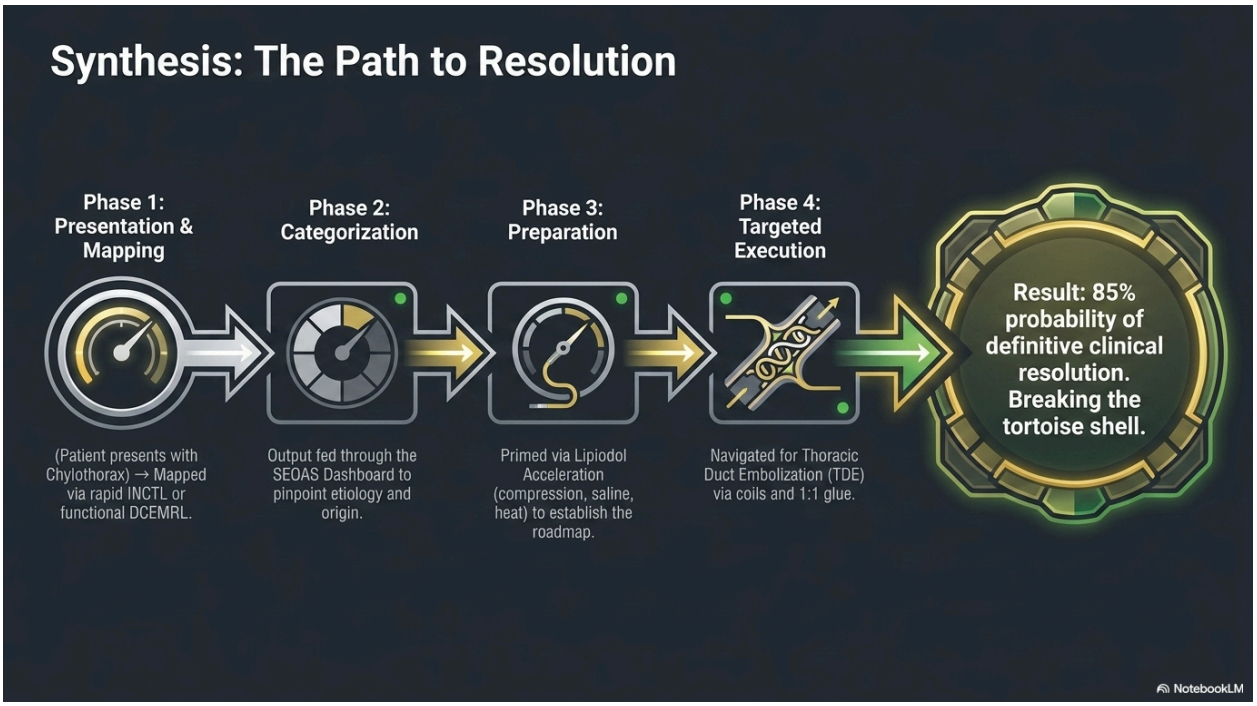


Figure 4: Flow diagram for path to resolution.

IX. Acknowledgements

ISVIR Lecture Series especially ones featuring Dr. Ashu Seth Bhalla, Professor and Consultant, AIIMS, New Delhi and Dr. Ajit Kumar Yadav, Consultant, Sir Ganga Ram Hospital, New Delhi for rekindling the urge to compile a lymphatic write-up. Dr. Maxim Itkin Luncheon Symposiums at Annual ISVIR Meet, 2026 which was a true masterclass on lymphatics from the pioneering expert on that sub-genre of interventional radiology.

Sri Siba Prasad Patra for his dedication and keeping the authors functioning during the compilation of the paper. Mrs. Ruma Das for managing the household.

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