Review Article

Lower Limb Edema: The Venous Factors

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Received: 01-05-2021/ Revised: 30-05-2021/ Accepted: 11-06-2021

Abstract

The life-threatening pandemic has been a whistle blower for many underlying diseases and pathologies. The sedentary lifestyle caused due to complete or phasic lockdown imposed by Government of India from time to time changed the way for our legs – from "running legs" to "stay at home legs". This may pose a threat for another pandemic ready to manifest- the lower limb edema. Taking into consideration the iceberg presentation for this disease, the authors highlight the normal anatomy of venous channels of lower limb so that various rehabilitative exercises and strategies may be planned for "sit and remain fit" mode of living. The article discusses the types of veins -the superficial, the deep and the communicating veins with their normal anatomy, microanatomy and reasons for blood stasis manifesting as edema of lower limbs.

Keywords: Lifestyle, Lower Limb Edema, Venous Channels, Rehabilitation.

Introduction

Edema is one of the most important cause of lower limb swelling, occurring due to increase in tissue fluid in the interstitial spaces. It usually manifests as palpable, visible swelling in the dependent parts of the body, generally the lower extremities and hence referred to as peripheral edema. Even a prolonged sitting or standing posture may produce edema (orthostatic edema) but that is generally reversible unless associated with an underlying pathology [1]. The peripheral edema may be unilateral or bilateral, systemic or localized and disrupts the normal fluid balance mechanism causing an accumulation of fluid in the interstitial spaces. Congestive cardiac failure, renal diseases, hypoalbuminemia, protein losing nephropathies, anaemia and even severe drug reactions are some of the systemic causes of edema where limb edema is either one of the indicators of underlying localized pathology or may be a part of generalized swelling, anasarca, not associated with posture. Various localized factors are also significant in producing unilateral, at times localized swelling and include chronic venous diseases, deep vein thrombosis, lymphedema, cellulitis, rupture of a Baker's cyst or a muscle, post-operative complications following a regional surgery and idiopathic edema [2].

Any excess intake of salt and increase in environmental temperature may also contribute towards edema. Gestational edema is the term referred to the peripheral edema occurring in the third trimester of pregnancy [3]. This is reversible and occurs due to compression of large veins of pelvis and abdomen by the developing embryo within uterus.

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The major anatomical factors that contribute in deranged accumulation of fluid in the interstitial spaces are:

(i) **Obstruction of venous channels** causing increased hydrostatic pressure within [4]

(ii) **Increase in capillary permeability** causes decrease in oncotic pressure within vascular compartment [5][4].

(iii) **Obstruction in lymphatic channels** (due to microfilaria, post-surgery or after radiation therapy, tumors etc)[6],[7],[4].

This review article discusses the complete anatomy of venous channels of lower limb and highlights the major reasons for cause of venous edema. The venous anatomy of lower extremity is of utmost significance to reach to a correct diagnosis and plan a management protocol.

Normal Venous Anatomy of Lower Limb

The peculiarity of venous anatomy for lower limb lies in the direction of blood flow which is against gravity in a cephalad direction towards the heart. This emphasizes the need for various modifications in the venous walls as well as in the surrounding anatomical structures which supplement this ante-grade flow of blood. Any disease pertaining to vessel per se or any obstruction to venous return (due to surrounding structures) can produce the signs and symptoms of edema of the lower extremity.

The veins of the lower extremity are classified as superficial veins, deep veins and perforating or communicating veins. This categorization is as per their location with respect to the fascial compartments in the lower extremity.

Fascial Compartments of Lower Limb

Lying under the epidermis part of the skin lies the dermis with superficial papillary and deep reticular layer. The papillary layer provides mechanical anchorage and the reticular layer being made of bundles of collagen fibers interspersed with elastic fibers bears the local mechanical stress. Underlying the dermis is a layer of superficial fascia, also called as hypodermis (clinically referred as saphenous fascia). It is a layer of loose connective tissue with abundant fat in its superficial aspect and deeper part with scanty fatty tissue being referred to as membranous layer. Lying deeper is the deep fascia

(clinically mentioned as muscular fascia) which covers and blends with the epimysium of the underlying muscle. Thus, this fascial organization creates compartments where runs vessels and nerves, classified accordingly.

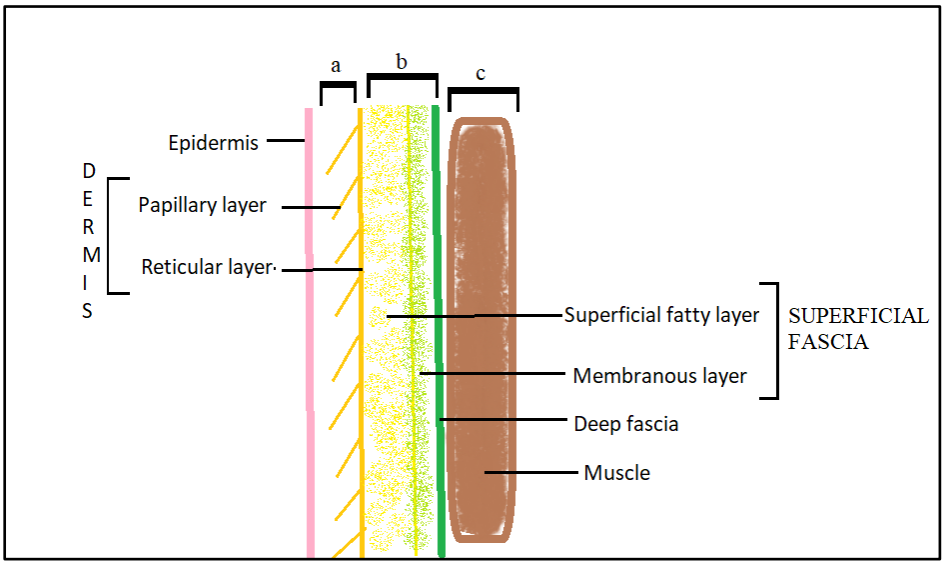

Fig 1: Fascial compartments of lower limb; a- dermis, b-superficial fascia, c-deep fascia/space

A. The **Superficial Veins** are located in

(i) Dermal or subdermal space, a plane either in the papillary/ between papillary-reticular layer (compartment a in Fig 1) or just below the reticular layer. There are small venulae surrounding the capillary network present in this plane. They are less than 4 mm in diameter and have valves as in other larger superficial veins. These are the *reticular veins*, unnamed, numerous and clearly visible as bluish lines in very thin and fair skinned individuals. Their prevalence is extremely high, reaching up to 60% in some populations, being more common in women, and the presence increases with advancing age. They are more of aesthetic significance than of clinical relevance[8]. The term epi-fascial veins is used for veins traversing just below the reticular layer of the dermis[9].

(ii) Hypodermis (superficial fascia), also called as subcutaneous space, are located just over the deep fascia (compartment b in Fig 1). The major trunks of the veins lie in the deeper layer of this compartment where the fatty content is scant while the tributaries are located more superficially surrounded by enormous amount of fat. The fat renders support to the traversing veins but also allows capacity for dilatation of veins in cases of reflux or stasis. The major superficial veins located in membranous part of this space are the great and short saphenous veins, while their tributaries are located in the superficial fatty part. As these veins lie in a compartment encased by superficial and deep fascia, clinically these are referred as inter-fascial veins. Vascular ultrasonography has suggested an "Egyptian eye" anatomy for their location[10].

These veins are medium sized with variable diameters between the individual veins as well as throughout their entire length[11][1]**.** The veins are thin walled surrounded by thick layer of tunica adventitia for strength and support. The muscular layer, the tunica media is made of three layers of muscle with number of collagen and elastin fibers interspersed between them. The innermost endothelial or tunica intima is made up of single layer of endothelial cells resting on a basement membrane. These cells have high anti-thrombogenic feature to render the smooth flow of blood. However, any injury or shear force trauma may rupture the endothelial lining to further disrupt the functional ability of these cells. The cells start secreting different molecules and cytokines, many of which may be vasodilators [12][13][2]**.** The endothelial lining at innumerable sites also undergoes modifications to produce infoldings supported by connective tissue framework- the valves. The valves are bicuspid and the number is usually variable. The presence of valves within the luminal surface facilitates the segmental flow of blood in the direction towards heart. The following superficial veins need a special mention:

- The ***Great Saphenous Vein*** **(GSV),** the pre-axial vein of lower limb(14) is the continuation of medial marginal vein (MMV) which drains blood from medial aspect of great toe. The MMV joins the medial aspect of dorsal venous arch (DVA) more distally near ankle and ascends anterior to the medial malleolus to reach the leg. It runs obliquely upwards in an anteroposterior direction to reach the posteromedial aspect of knee joint (about one hand breadth behind the patella). Continuing further it moves posteriorly behind the condyles of tibia and femur and gradually comes to lie on the anteromedial aspect of thigh. It runs further proximally and finally pierces the cribriform fascia, a modification of deep fascia of the thigh, before draining into the femoral vein located in the femoral triangle (Fig 2). Throughout its course the GSV lies in the superficial fascia except at its termination where it pierces the deep fascia to drain into the femoral vein. The saphenous nerve lies anterior to the vein at the ankle and may be injured during "cut-down" procedures in emergency transfusion. The vein has around 10-12 valves which are significant in preventing the retrograde flow of venous blood and work as blood flow modulators[15][16][17] .The valves may be located at the sites of ostia (referred to as terminal valve) or may be at sub-ostial level (referred to as para-terminal valves).

Throughout its course, number of tributaries join to drain into the GSV and running in the comparatively superficial aspect of superficial compartment, these venous tributaries are of more clinical relevance in chronic venous insufficiency [9].

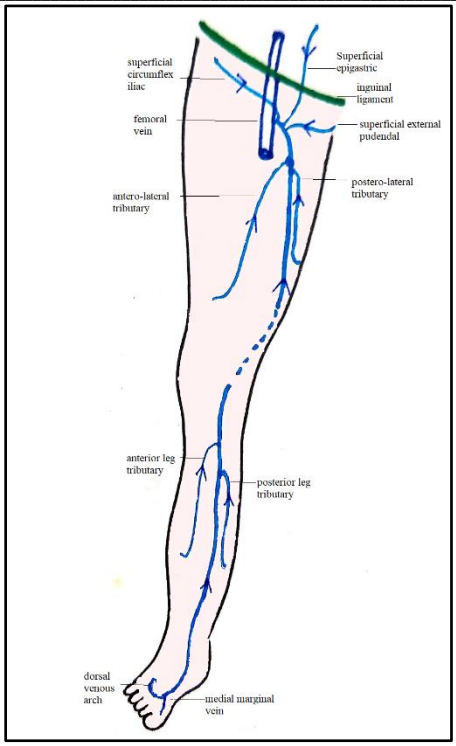

Fig 2: Course and tributaries of GSV

The various sites of tributaries are as under:
(a) At the ankle- the *medial marginal vein* which drains the sole
(b) In the leg- number of *communicating veins* connects it with short saphenous vein. *Posterior arch vein* collects blood from the posteromedial side of calf.
(c) Just below the knee- *anterior veins of leg* collect venous blood across the shin and drain it into GSV directly or via the posterior arch vein. From the tibial malleolar region and from the calf region also unnamed tributaries drain into GSV.
(d) In the thigh- an *anterolateral vein* collecting blood from the anterior aspect of thigh drain into the GSV at the upper part of thigh. A *posteromedial vein*, also called as accessory saphenous vein, drains blood from the posterior and medial aspect of thigh.
(e) Just before it pierces the cribriform fascia- three constant veins lie at this level, *the superficial circumflex iliac, the superficial epigastric and superficial external pudendal veins*. These three veins drain the anterolateral aspect of abdominal wall and perineum. At this site the femoral vein itself may receive a thoraco-epigastric vein that runs superficially in the lateral aspect of trunk draining blood from number of lateral thoracic veins.
(f) At saphenofemoral junction- here it receives the *deep external pudendal vein* which drains blood from the anterior part of perineum.
The ***Saphenofemoral Junction*** **(SFJ)** is an important site for two reasons, firstly because it is the site of termination of this superficial vein, it traverses into small part of deep fascia before draining into femoral vein and a valve, Saphenofemoral Valve (SFV) is stated to be present in 94% to 100% individuals. It is usually stated to lie 2.5 cm inferior and 4 cm lateral to the pubic tubercle. The SFV is supported by a subostial valve or pre-terminal valve located just distal to the SFV and also by another valve, present in about 81% of individuals, above SFJ in the external iliac vein (Supra-Saphenic Valve). The supra-saphenic valve may render support to the SFV in withstanding the reflux hydrostatic pressure of blood column from abdomino-pelvic region [17]
The tributary of deep external pudendal vein opens at the SFJ while the rest three superficial tributaries (vide supra) open anywhere between the terminal and paraterminal valve. Together these drainage site represents a site of confluence of veins referred to as *confluens venosus subinguinalis.* With the advent of technical advancement, use of duplex ultrasonography, it is possible to assess the real time location, function and tributaries located at this junction. A normal SFJ relies on the integrated functioning of each of the component parts located at this level and number of variations have been reported at this site which are significant clinically [18]. Even the saphenous vein may show duplication at this level, though the occurrence is reported to be as rare as 1%.

- **The *Short Saphenous Vein* (SSV),** the post-axial vein of developing limb bud, begins behind the lateral malleolus as continuation of lateral marginal vein with dorsal venous arch. Here it lies in relation to the sural nerve which is just lateral to it. The vein then ascends lateral to the tendon of Achilles in the midline of posterior leg. It then perforates the deep fascia at the margin of gastrocnemius muscle and runs a sub-fascial course to finally drain into the popliteal vein[19] (Fig 3)

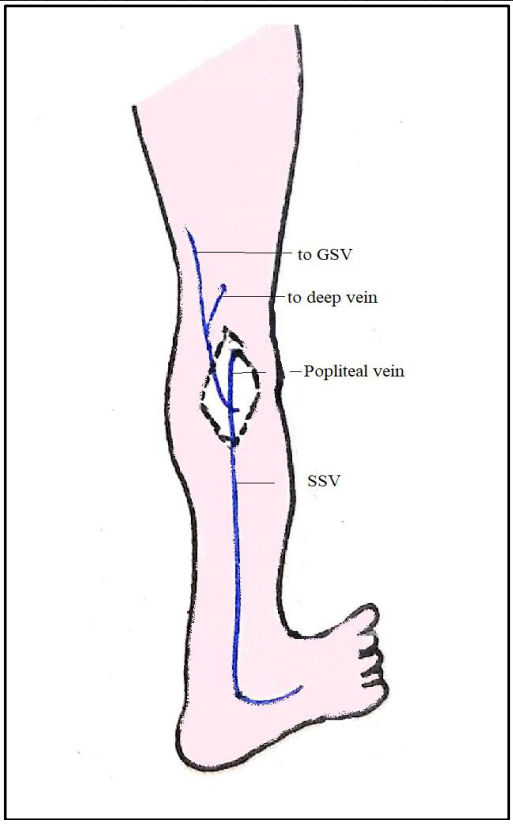

Fig 3: Course of SSV

It presents 7-13 valves though-out its course and the one located at sapheno-popliteal junction is invariably constant. It has stronger and thicker wall than that of GSV. The SSV collects several tributaries such as the lateral marginal vein or the lateral malleolar plexus [14] Number of muscular veins from gastrocnemius, biceps femoris and semimembranosus also drain into it. A cranial extension of the small saphenous vein, often referred to as the vein of Giacomini, may ascend posteriorly in the thigh to communicate with the great saphenous vein through the posterior thigh circumflex vein [20].

The **Saphenopopliteal junction** invariably presents number of variations. The SSV may drain into the popliteal vein at this level or may have a high up thigh extension to drain directly into the GSV. When SPJ was present then also there occurs dense venous web which have number of muscular veins draining into them.

B. The **Deep Veins** are located deep to the deep fascia either as intramuscular or intermuscular veins and follow the arterial circulation. Below the level of knee these veins usually run in parallel to the corresponding arteries, the two segments being connected by a communicating vein. Above the level of knee, they run as single large vein parallel to the artery. These veins are valved with number of valves decreasing from caudal to cranial. The *medial and lateral plantar veins* drain the sole, venae comitantes of dorsalis pedis artery form the *anterior tibial vein*. Their tributaries correspond to that of branches of corresponding arteries. Another deep vein, the *peroneal vein* joins the *posterior tibial vein* after runs along the posteromedial aspect of the fibula and joins the *posterior tibial vein*. The anterior tibial vein unites with posterior tibial vein at the distal border of popliteus muscle to form the *popliteal vein*. The posterior tibial vein receives tributaries from majority of the soleal sinuses (vide infra)and from SSV. The popliteal vein tributaries correspond to branches as of the popliteal artery and also may receive the SSV. The popliteal vein continues above the adductor hiatus as the *femoral vein* which receives tributaries from the superficial system of veins and *profunda femoris vein*. The lateral and medial circumflex veins are constant tributaries draining into the femoral vein. All these deep veins are valvular except those draining the soleus muscle which are valveless in form of soleal sinuses, 1-18 in number [21] (ref*: muscle pump failure*).

The femoral vein continues behind the inguinal ligament as *external iliac vein* which joins with *internal iliac vein* to form the *common iliac vein*. The duplication of internal iliac vein is reported in around 27% of extremities and the variation is more commonly on the right side[21]. The tributaries of external iliac vein are the pubic veins, inferior epigastric vein and deep circumflex iliac veins and the internal iliac veins drain venous blood from majority of the pelvic viscera.

C. The **Perforating or Communicating veins** are a connection between the superficial and deep venous system and for this reason these veins pierce the deep fascia and the direction of blood flow is from superficial to deep veins. The veins run obliquely so that increase of pressure during muscle contraction causes the veins to compress and prevents retrograde flow from deep towards superficial system[22] The valves located within the luminal surface follow the direction of blood flow. With respect to their connections and locations they are of two types: (i) *direct perforators* which directly communicate between anyone of the superficial vein to the underlying deep vein and (ii) *indirect perforators* which passes through the substance of the muscle to finally drain into a deep vein. (Fig 4) An important indirect perforator is soleal sinuses located within the substance of soleus muscle. They are un-valved venous sinuses which pump their venous blood into the deep veins due to muscle contractions. They empty segmentally into the tibial and peroneal veins.

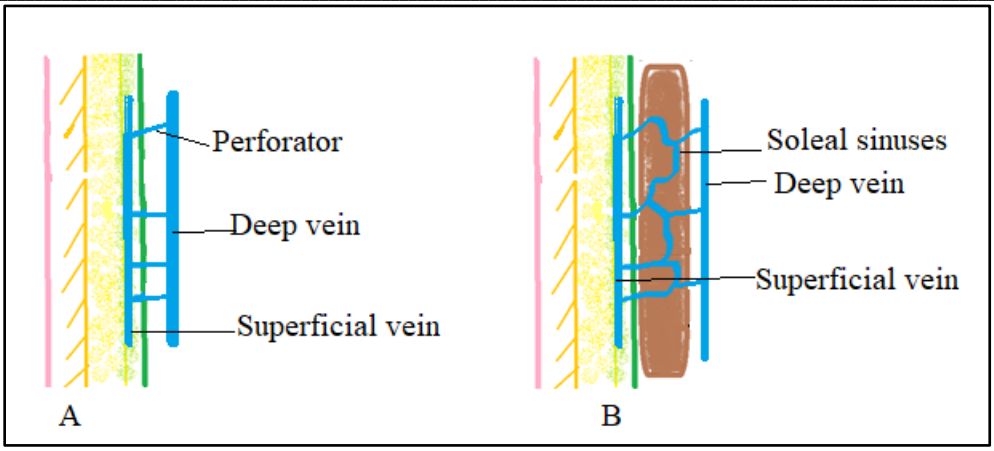

Fig 4: Direct (A)and Indirect Perforators (B)

The perforators are named as per their location anatomically and they are[23][22] (Fig 5)

(i) Adductor canal perforator, present in the middle third of thigh in the adductor canal. It connects the GSV or one of its tributaries into the femoral vein. Clinical nomenclature is as Hunterian or Dodd perforator.

(ii) Below knee perforator, located just distal to the knee to communicate between the GSV or the posterior arch vein to the tibial vein. Clinically referred to as Gastrocnemius or Boyd's perforator.

(iii) Medial ankle perforator, usually three in number located in line with posterior border of tibia at a distance of 5,10 and 15 cms from the medial malleolus.

(iv) Lateral perforator, located laterally at the junction between the lower and middle third of leg connecting the SSV or one of its tributaries to the deep peroneal vein.

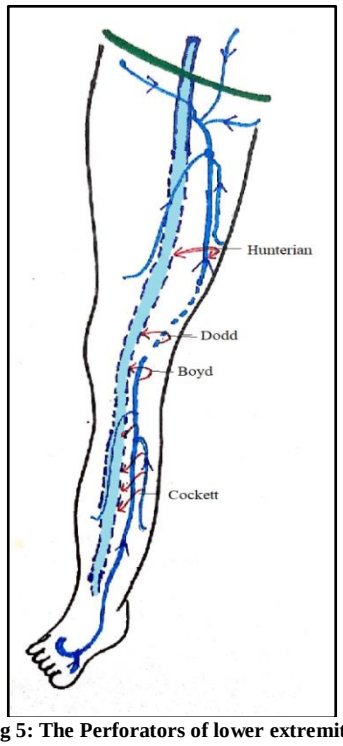

Fig 5: The Perforators of lower extremity

Any derangement of this normal anatomy of either the veins or the valves within may be the prime reason for the manifestation of peripheral oedema. The underlying text describes the causes and anatomical alterations a vein undergoes during oedema.

Anatomy of venous channels in oedema

Causes of venous oedema are:

In superficial veins- superficial thrombophlebitis, varicosity

In deep veins- deep vein thrombosis and chronic venous insufficiency

In perforating veins- valvular defects and calf muscle pump failure.

Superficial or Deep Vein Thrombophlebitis are conditions where there occurs stasis of blood within the vessel wall causing endothelial injury. The vascular derangement releases number of chemical mediators which cause dilatation of vessels to further accentuate stasis and cause sluggish blood flow producing a blockage due to clot or thrombus formation. The Great and Short saphenous veins are more prone for thrombophlebitis being nearer to the skin surface. The DVT

occurs commonly post-surgery immobilization or prolonged ambulatory phase of the extremity.

Varicose Veins **(varicosity)** are short tortuous segments of superficial veins clearly visible on the skin surface, occurring due to vessel wall diseases or due to incompetency of valves producing a retrograde blood flow. There occurs pooling of blood in the distal segments of veins, causing their dilatation. The ostial and sub-ostial valves present in the superficial venous system which otherwise help to maintain the pressure of the hydrostatic column become incompetent causing reflux of the blood flow. This incompetency can occur in any one of the tributaries of the vessel or the major vessel trunk itself. The intimal layer presents irregular thickening, fibrosis of collagen fibers within the muscular layer, loss or atrophy of elastic fibers, disorganization of tunica media with thickening of adventitia. All these changes produce sequential valve failure due to separation of valve leaflets produced by dilated vessel segment, leading to incompetency and reflux.

Chronic Venous Insufficiency otherwise referred to as venous hypertension, occurs due to aplasia or hypoplasia of valvular patterns of deep or superficial veins. Individuals with absence of SFV or valve in external iliac veins are more prone for chronic venous insufficiency. There may be congenital weakness of vessel wall which usually affects the deep veins producing non-compliance and resilience against blood flow. This causes stagnation of blood flow leading to endothelial damage and the cyclical changes producing vein dilation. In other instances, there may be no valvular incompetence, instead obstruction to venous blood flow due to pre-existing pathology in form of tumor, growth or even a physiological hypertrophy of uterus during pregnancy may lead to venous insufficiency. Muscle dysfunction, rupture may cause failure of the pumping mechanism to maintain the pressure gradient.

Muscle Pump Failure predominantly refers to calf muscle failure, though other skeletal muscles of the thigh also act as pump for redistribution of pressure within the vessels. The calf muscle contractions are helpful in maintaining both vertical and horizontal redistribution of venous blood [24]. The horizontal flow occurs when during muscle contraction, the blood is pumped from the deep to superficial vein. This is a normal physiological response and the competency of valves; a healthy vessel wall affectively maintains the transient increase in pressure. In the relaxation phase the flow occurs from superficial to deep veins. The vertical flow of blood occurs when muscle contraction elevates the pressure to transmit the blood from popliteal to femoral vein, if the valvular competency is normal.

Conclusion

This brief anatomy of venous channels of lower limb may be good guide to surgeons and plastic surgeons in planning a surgical procedure for correction of venous disorders of the extremity. A thorough knowledge of presence and location of valves may serve a reasonable tool while performing valvular ultrasonography. A forthcoming article by the authors will discus the lymphatic factors responsible for edema.

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Conflict of Interest: Nil
Source of support: Nil