

Lower limb veins color and spectral Doppler ultrasonography examination.



An examination protocol

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Lower extremity's venous pathology was traditionally investigated by intravenous venography. Nowadays Color Doppler flow imaging is widely accepted as a well established, noninvasive method for the evaluation of deep pelvic and lower extremity's venous system. The vast majority of authors conclude that the method can safely replace diagnostic venography in all patients with venous thrombosis, thrombophlebitis and valve or communicating veins insufficiency.

Optimal performance of Color Doppler flow imaging as a diagnostic tool for the whole lower limb veins requires:

- proper equipment specifications and settings
- knowledge of regional venous anatomy
- established examination protocols
- evaluation of morphological and functional findings
- documentation of the findings.

All these steps are described as a sequence of guidelines, photographs and multiple ultrasonographic images. Our paper can be useful to all physicians or sonographers involved with color Doppler studies for the evaluation of lower limb venous diseases and abnormalities.

KEY WORDS: Color Doppler, Ultrasonography, Veins.

Equipment Settings

In the pelvic region and the adductor canal, linear-array transducers (ranged 3.5-5MHz) should be used usually compressed over the area of interest in order to provide better depth resolution. For the limb, linear broadband transducers (ranged 5-7.5-10MHz) are preferred, because the examined veins are superficially located.

As a rule the examined vein must always be in the correct focal zone and Color coding and spectral parameters have to be adjusted properly to obtain optimal image findings. Because of the relatively slow venous flow, velocities ranging from 20 cm/s to less than 1 cm/s must be used. Flow direct toward the heart should be adjust-

ed to indicate an upward deflection. Low color wall filter (50 to 100Hz) will give the best visualization of the color flow by avoiding wall and/or tissue motion. Color gain must be low enough to prevent acoustic noise so no artificial flow can be depicted outside the vein, while at the same time bright color flow should be seen inside the vein. Color box (or window) must be adjusted in position and size exactly for the region of interest.

Otherwise, by unnecessarily increasing color box width, the frame rate decreases. Beam steering allows the operator to direct the color flow beams at a preset angle. Ultrasonographic beam-to-flow angle, according to the Doppler formula, must be between 0° and 60°, in order to maintain reliable Doppler measurements. Angle correction should be applied in order to determine flow velocity, and must be kept at approximately the same value when following the course of an axis, in order to produce quantitative measurements. Sample volume must be as small as possible and always in the center of the vein. Aliasing can be avoided by increasing pulse repetition frequency (PRF), or by lowering the baseline¹.

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Lower Extremity Venous Anatomy

Deep Venous System

Deep veins of the leg and pelvis accompany the arteries and have the same name as the arteries ¹.

Peripheral level

Dorsal veins of the foot as well as the medial and lateral plantar veins form the deep venous system that drains blood from the foot to the leg. These veins are connected to the superficial root. Anterior and posterior tibial and peroneal veins form the deep venous system of the lower leg. Each venous system is composed of two veins running along either side of the corresponding artery finally forming a main trunk, called the popliteal vein either distal to the knee joint (in 46% of cases), at joint level (in 13% of cases) or proximal to it (in 40% of cases) lying superficial to the popliteal artery. After the popliteal vein enters the adductor canal it becomes the superficial femoral vein ².

Two groups of veins that are classified as belonging to the deep veins are the gastrocnemic and soleal veins and these are embedded in the gastrocnemius and the soleus muscle respectively, and ultimately join the popliteal vein. They are particularly important from a clinical perspective due to their tendency to form localized thrombi ².

Thigh level

The superficial femoral vein continues through the thigh and joins the deep femoral vein 2-7cm below the inguinal ligament. From this point it is called the common femoral vein and lies medially to the corresponding artery. A normal unpaired form of this vessel is found in 62% of cases and a completely paired superficial femoral vein occurs in only 3% of cases. In 21% of cases there is a division in the distal segment and in 13% of cases multiple veins are found. In patients with deep venous thrombosis there is a high prevalence of duplicated femoral segments ¹.

Pelvic level

Above the inguinal ligament the common femoral vein becomes the external iliac vein. The junction of the external iliac vein (which drains the lower extremity) and the internal iliac vein (which drains the pelvic viscera and musculature) produces the common iliac vein. It unites with the inferior vena cava at the level of the body of the fifth lumbar vertebra. Confluence of the two common iliac veins occurs to the right of the spine. Shortly before originating the right common femoral vein, is crossed by the right common iliac artery. At this point the so called "venous spur", can form a membrane that projects into the lumen and obstruct it. Evaluation of the spur is of great importance since it represents a potential thrombogenic obstruction to blood flow ².

Superficial Venous System

Great saphenous vein

The great saphenous vein originates from the superficial veins at the medial margin of the dorsum of the foot and passes anterior to the medial malleolus to continue to the medial aspect of the leg.

It joins the common femoral vein approximately 4cm below the inguinal ligament. This junction point is often dilated into a funnel shape with its diameter measuring up to 2.0 cm. Approximately ten valves are encountered along its course and in 27% of cases it is paired ².

Minor saphenous vein

The minor saphenous vein originates from the lateral margin of the dorsum of the foot and passes dorsally to the lateral malleolus and extends along the posterior aspect of the calf between the two heads of the gastrocnemius muscle. It enters the popliteal vein usually at knee-joint level ³. The most common variant is for the vein to continue up to the thigh and enter the deep system or the great saphenous vein in the upper thigh ⁴.

Perforating Veins

The deep venous system communicates with the superficial venous system through the perforating veins. Normal flow of blood is from the superficial to the deep venous system. This happens when the calf muscles relax and the pressure in the calf deep veins drops below that of the superficial system. The valves open allowing the blood to flow from the superficial to deep veins. This function empties the superficial system and fills the deep veins.

When the muscles in the calf contract the perforating valves close and blood flows from the high-pressure calf into the lower-pressure popliteal and superficial femoral veins. Reverse flow is impeded by the valves of the perforating veins ⁵.

Dodd veins at the medial distal thigh are the most clinically important perforating veins. At this point they connect the great saphenous vein to the femoral vein. Also important are the Boyd (proximal lower leg) veins that are found inferiorly and medial to the knee joint.

Finally, Cockett (distal lower leg) veins that lie above the sole of the foot connect the great saphenous vein with the posterior tibial veins ².

Examination Protocol

A brief history is taken to define symptoms, previous surgery and relevant risk factors. The examination is started with the patient in the supine position and with a slight elevation of the upper body in the elderly ^{2,3}. Initially the external iliac vein is identified at the groin above the inguinal ligament. The examination continu-



Fig. 1: Probe positioning along course of the common femoral vein.



Fig. 2: Probe positioning in the groin. Common femoral vein is identified directly medial to the common femoral artery.

ous in a cranial direction, with long axis imaging until the vessel dives deeply into the pelvis (Fig. 1). Until this level the vessel can be well displayed and be easily compressed. From this point the transducer is located lateral to the rectus muscle and the external and common iliac veins are followed with the goal of tracing the iliac system all the way to the inferior vena cava.^{1,3} Patency of the iliac veins is usually assessed indirectly by using pulsed-wave Doppler assessment of the common femoral vein blood flow pattern⁵.

In a transverse plane in the groin the common femoral vein is identified directly medial to the common femoral artery (Fig. 2). The course of the vein is followed caudally in order to find two important landmarks: the great saphenous vein and the junction of the superficial and deep femoral veins. At this point patency of the deep femoral vein should be confirmed. The common femoral vein is examined in detail; transverse compression is used for checking the patency (Fig. 3) and a Doppler spectrum is used for the evaluation of respiratory fluctuations during a Valsalva maneuver³.

Evaluation of flow in the common femoral vein and the Valsalva response are used to exclude thrombosis of the iliac veins or the inferior vena cava⁵. Next the superficial femoral vein is followed all the way to the adductor canal. A full length of the vein must be sampled with images parallel to the vein and patency of the vessel must be checked by transverse compression at approximately 2cm intervals⁵. The adductor segment of the superficial femoral vein is too deep to be effectively compressed in most patients, so it is useful to compress the vessel with a hand underneath the lateral thigh during the examination, or to use color Doppler imaging^{3,7}.

Evaluation of the popliteal vein can be achieved with the patient placed in a prone position (Fig. 4) with his/her ankle slightly elevated and supported suitably. The popliteal vein is imaged at the posterior aspect of the knee. It is followed upward all the way to the adduc-

tor canal until the distal part of the superficial femoral vein is seen. Then compressibility of the popliteal vein in transverse section is confirmed (Fig. 5).

It is important to check for popliteal and superficial vein duplication in order to evaluate possible deep venous thrombosis in one channel only of a duplicated system². Proceeding distally, the division into the three lower leg veins occurs. It is important to evaluate these veins because asymptomatic high-risk patients usually have smaller and often non-occlusive thrombi frequently isolated to the difficult to visualize calf veins⁷. A seated position is preferred for improved display of the calf veins, although the supine with head raised position is recommended for elderly patients². The posterior tibial vein is located along the medial aspect of the leg and can usually be found at the level of the medial malleolus. It is scanned cranially to its junction at the tibial trunk (Fig. 6).

From the same medial approach from where the posterior tibial vein is seen, the peroneal vein can be seen too, but deeper in the scan plane (Fig. 7). Peroneal visualization sometimes requires a more posterior approach, as it lies on the "stocking seam" of the leg. The anterior tibial vein is best visualized from an anterolateral approach (Fig. 8) with the transducer positioned between the tibia and the fibula⁵. Using the corresponding arteries as guiding landmarks these veins are examined along their course with longitudinal and transverse sections, with and without compression. Their bifurcations should be also imaged^{1,3}. Blood flow is generally not spontaneous in the calf veins, and flow must be augmented by periodic manual compression of the foot or the lower portion of the calf⁵.

When symptoms suggest superficial vein thrombosis, great saphenous and small saphenous vein should be examined in detail with the patient standing¹⁻³.

These veins are followed along their anatomical course and their patency is checked with transverse compres-

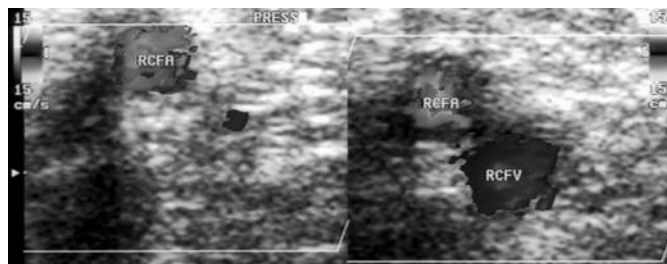


Fig. 3: Junction of the superficial and deep femoral veins.

sion. Valvular competence is evaluated with Valsalva maneuver or compression at a more distal level³. Perforating veins are usually examined in their typical anatomical location (Fig. 9) when there is a clinical suspicion of their insufficiency. The contra lateral extremity should be evaluated if clinically indicated².

Evaluation of Morphological and Functional Findings

General Ultrasonographic Normal and Abnormal Vein Characteristics

In a longitudinal section the venous lumen is anechoic and the interior surface of the vein wall is smooth. The wall itself is so thin that it cannot be seen and no arterial pulsation can be seen.

A patent vein lumen can be obliterated by a small amount of extrinsic pressure. In cases of acute thrombosis the thrombus can be recognized by its greater echo intensity, although the lumen cannot be obliterated with compression. Visualization of the thrombus itself is not a reliable sign however the echogenicity of the thrombus is quite variable ranging from virtually anechoic to more echogenic than muscle. Using color Doppler flow imaging, a thrombus is suspected by the absence of color however sometimes color does not fill the vein because the equipment singular settings selected are not sensitive enough to depict the slow blood flow. On the other hand "overgaining" may cause color to bleed into surrounding tissue and may obscure partial thrombus ⁵. The most important aspect of the venous evaluation is to determine how the vein responds to compression by the transducer ^{1,5}.

Lack of compressibility of the vein is perhaps the single most reliable finding for differentiating between thrombosed and normal veins ^{1,3}. Vein compressibility is best checked in a transverse section because a false impression of compressibility may occur with long-axis views as the vein may slip out of the image ³. In the case of

acute thrombosis the vein is substantially larger than the corresponding artery (because thrombus distends the vein lumen) and there is not a visible modulation due to respiration. This distending pressure is the source of some of the pain that is experienced by the patient with acute thrombosis. Venous size may also be increased by back-pressure from congestive heart failure or venous reflux. Enlargement shows therefore, once again not be the sole criterion for the diagnosis of venous thrombosis ¹. The major veins of the thigh are somewhat larger in diameter than their corresponding arteries and their size varies with respiration.

Also the diameter of large leg veins increases with respiration.

However, veins with chronic deep venous thrombosis tend not to be dilated, may have irregular channels, color-encoded blood flow within the lumen, and will often have thickened, poorly compressible vein walls (even if the lumen is completely recanalized) ⁷.

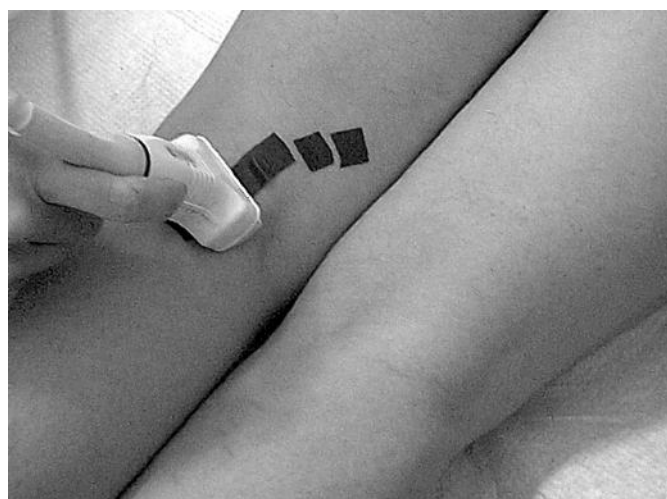


Fig. 4: Evaluation of the popliteal vein can be achieved with the patient placed in a prone position.

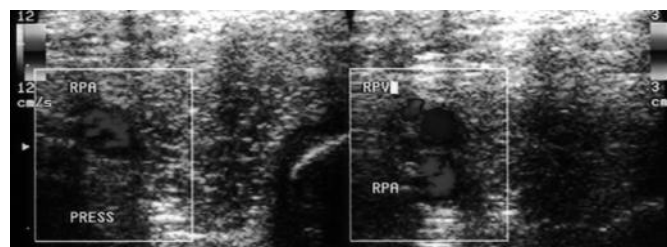
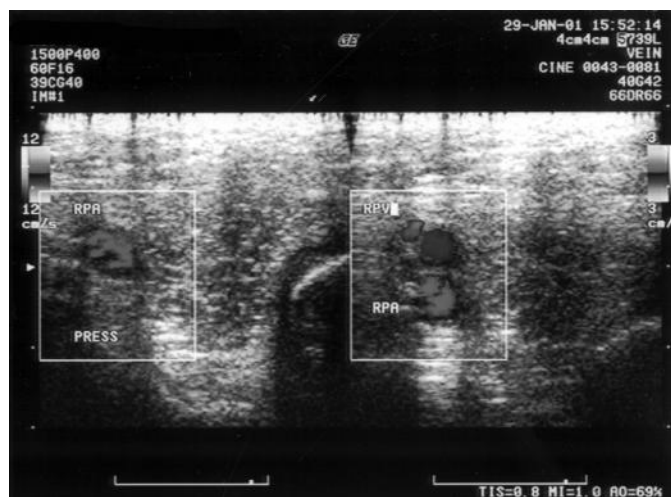


Fig. 5: Compressibility of the popliteal vein should be confirmed in transverse scan.

Doppler Characteristics and Diagnostic Manipulation

Normal venous flow is phasic (Fig. 10) and the velocity of flow changes in response to respiration. Expiration causes an increase of venous flow in the lower limb, while an almost complete cessation of blood flow follows in the late respiratory phase (Fig. 11). On occasion, loss of this normal respiratory change may be due to low blood volume or increased right-sided heart pressures¹. However, many times a continuous flow will indicate the presence of substantial obstruction proximally, or sometimes distally, to the site of Doppler examination. A phasic pattern may persist when thrombus does not substantially obstruct the vein lumen;³ therefore the identification of a phasic flow pattern does not exclude thrombosis entirely but only excludes thrombus that occludes the vein lumen. After the obstructed segment is localized and checked with compression, presence or absence of blood-flow signals may be interrogated with color Doppler.

Manual compression of the extremity distal to the site of the examination increases venous flow (Fig. 12 a-b). This response (signal augmentation) confirms substantial patency of the veins between the site of Doppler examination and the site of venous compression. Proximal compression is used to check valvular function. Sufficient valves produce a cessation of blood flow during compression. This maneuver is used mostly for the calf veins².

Valsalva manipulation is principally used to document the sufficiency of valves of thigh veins. Deep inspiration followed by bearing down increases thoracic and abdominal pressure and can result in an abrupt cessation of blood flow in large and medium-sized veins. The response profile documents the patency of the venous system and is particularly useful which segments that cannot be directly examined^{2,3}. Loss of normal response may be secondary to either acute vein thrombosis or extrinsic obstruction of the iliac venous system (pelvic malignancy or pregnancy)⁵. Valvular incompetence is diagnosed by demonstrating retrograde flow in response to the Valsalva maneuver.



Fig. 6: Posterior tibial vein is located along the medial aspect of the leg.



Fig. 7: Peroneal vein can be seen too, but deeper in the same scan plane for the posterior tibial vein.



Fig. 8: Anterior tibial vein is best visualized from an anterolateral approach with the transducer positioned between the tibia and the fibula.

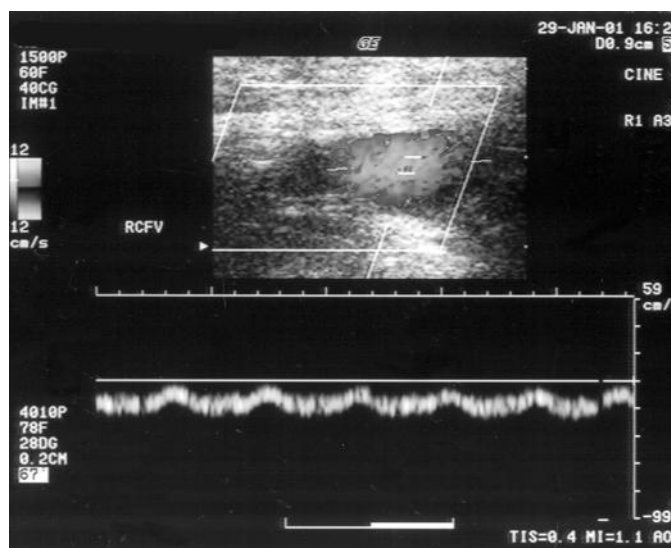


Fig. 10: Normal venous flow Doppler characteristics.

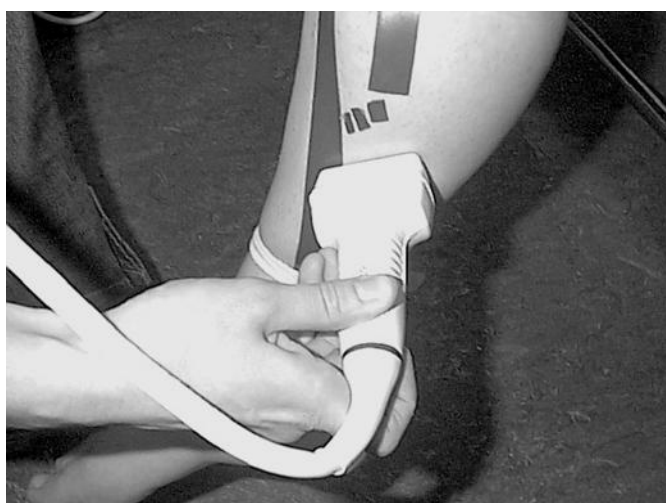


Fig. 9: Typical anatomical location of perforating veins.

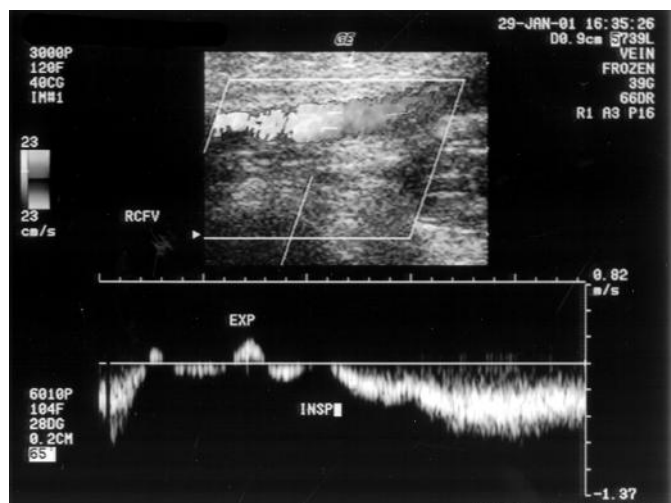


Fig. 11: Expiration causes an increase of venous flow in the lower limb, while an almost complete cessation of blood flow follows in the late respiratory phase.

When venous valves are insufficient, flow fails to stop during this maneuver and it has a centrifugal direction of varying duration.

During the Valsalva maneuver a blood flow reversal of less than 0.5 second is normal and related to the time required for valve closure. Blood flow reversal of greater than 0.5 second is suggestive of valvular incompetence, whereas flow reversal exceeding 2 seconds is definitely pathologic.⁷

When testing the sufficiency of perforating veins the patient is seated in an upright position and a tourniquet is placed to compress and obstruct the venous flow through the epifascial veins. The tissue distal or proximal to the tourniquet, is compressed. During the compression, venous flow is registered through the insuffi-

cient valve of the perforating vein toward the surface and approaching the probe ².

Documentation

All images taken should be marked with the examination date, patient identification, image location and probe orientation. For the documentation of the normal leg veins, an attempt should be made to evaluate the full length of the distal inferior vena cava, femoral, popliteal and calf veins as well as the great saphenofemoral junction and the proximal segment of the great saphenous vein. Images, with and without compression should be recorded at each of the following levels:

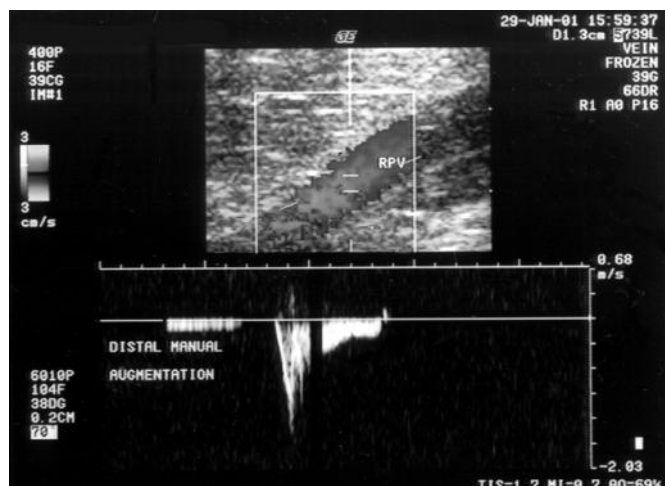


Fig. 12: Manual compression of the extremity distal to the site of the examination increases venous flow (signal augmentation).

- common femoral
- mid – femoral
- mid – popliteal veins
- saphenofemoral junction

Any other abnormality (e.g. lymph node, haematoma, pseudoaneurysm or other mass) should be documented.

Areas of focal tenderness should be documented as well.

Documentation of an abnormal area anywhere in the leg venous system includes: location and length of thrombosed lumens and Doppler flow recordings during deepened respiration, as well as during Valsalva maneuver. A medical report must be made.

Conclusion

This review will provide assistance to practitioners performing examinations of the lower limb venous system by the use of color and spectral Doppler ultrasonography. In our paper we describe the technique for the evaluation of the deep and peripheral venous system and we provide diagnostic criteria for detecting abnormalities that occur in these veins.

Riassunto

La patologia del tratto venoso delle estremità inferiori venne tradizionalmente investigata con l'uso della venografia intravenosa. Oggi il doppler di flusso a colori è una tecnica diagnostica per immagini largamente accettabile per lo studio del sistema venoso della profondità della pelvi e delle estremità inferiori, in quanto come tecnica risulta essere non invasiva, a basso costo e facilmente ormai ripetibile e reperibile nella maggior parte dei centri ospedalieri. La

maggior parte degli Autori infatti conclude che la suddetta tecnica può sostituire la venografia, in modo sicuro dal punto di vista della credibilità dei risultati, per la diagnosi delle problematiche legate alla trombosi venosa, alla tromboflebite ed alla insufficienza delle valvole venose o/e dei vasi venosi comunicanti. Per avere un risultato ottimale per lo studio della patologia del sistema venoso dell'intero tratto inferiore del corpo dalla tecnica diagnostica per immagini del doppler di flusso a colori, occorrono i seguenti: adeguate specificazioni per l'uso e la messa a punto dell'equipaggiamento utilizzato buona conoscenza dell'anatomia del sistema venoso della regione corporea che interessa studiare, uso di certificati ed accreditati, protocolli d'esame, buona valutazione dei reperti morfologici e funzionali buona documentazione dei risultati reperiti. Tutti questi passi vengono descritti in questo articolo attraverso una sequenza di guidelines, di fotografie e di multiple immagini ultrasuonografiche. In questo modo pensiamo che il nostro articolo potrà essere utile, quale punto di riferimento, a tutti i medici coinvolti all'utilizzo del doppler di flusso a colori, quale tecnica diagnostica per immagini, per la valutazione delle anomalie e delle patologie del sistema venoso della parte inferiore del corpo.

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