Imaging of Venous Insufficiency

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ABSTRACT

Duplex ultrasonography (DUS) is an essential part of the evaluation of patients with most forms of superficial venous insufficiency. DUS has also become an important tool in directing and assessing the results of a variety of minimally invasive treatments of this disease. In this article, we review the salient aspects of performing an adequate DUS evaluation and the utility of this technique in guiding treatment.

KEYWORDS: Superficial venous insufficiency, duplex ultrasonography, endovenous thermal ablation, ultrasound-guided sclerotherapy

Objectives: Upon completion of this article, the reader should be able to (1) understand the importance of performing duplex ultrasonography (DUS) for patients with most forms of superficial venous insufficiency (SVI), (2) understand how to perform DUS for patients with SVI, (3) understand the relevant normal and abnormal anatomy and physiology of the superficial venous system of the lower extremity as depicted by DUS, (4) understand how to use DUS to guide treatment for SVI, and (5) appreciate the DUS findings after endovenous thermal ablation of truncal vein incompetence.

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Duplex ultrasonography (DUS) has evolved to become the primary diagnostic tool used to evaluate patients with superficial venous insufficiency (SVI). Although other techniques exist, DUS is an inexpensive, portable, and reproducible means of simultaneously assessing both the venous anatomy and physiology. DUS is also an integral component of image-guided endovenous methods used to ablate incompetent truncal veins. In this article, we review the techniques of DUS evaluation of the superficial venous system and demonstrate its utility in guiding and evaluating the results of endovenous ablation.

INDICATIONS FOR ULTRASOUND EVALUATION

Clinical evaluation based solely on the distribution of the venous abnormality can suggest a pattern of incompe-

tence. Unfortunately, because several different patterns of incompetence can result in a similar appearance of abnormalities, treatment decisions based solely upon clinical evaluations are often fraught with errors. Therefore, it is strongly recommended that all patients undergoing evaluation for lower extremity varicose veins, edema, or venous skin changes (CEAP clinical stage 2–6) undergo an ultrasound study of the superficial venous system to determine the pattern or patterns of incompetence prior to making treatment recommendations. Patients with spider veins (CEAP clinical stage 1), particularly those in typical distributions such as on the lateral thigh area, generally do not require US evaluation. However, when the spider veins are found in the distribution of a large truncal vein such as the great saphenous vein (GSV), it is recommended that DUS be performed. If truncal vein reflux is identified and contributory in these cases, treatment of this

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reflux may be warranted prior to treatment of the spider veins.

DUPLEX ULTRASOUND ANATOMY

DUS is typically used to evaluate the GSV and the small saphenous veins (SSV) and their primary tributaries. These veins are found deep to the superficial and superficial to the deep fascia within the saphenous sheath (Fig. 1A and B). During axial or cross-sectional imaging, these veins have the appearance of Cleopatra's eye or of the Seattle Seahawks helmet logo (Fig. 1C and D).

The primary named tributaries of the GSV are also found within the saphenous sheath and therefore would have a similar appearance over portions of their lengths. These veins include the anterior and posterior circumflex veins of the calf and thigh and the anterior accessory GSV. However, the majority of the tributaries of these veins as well as of the GSV and SSV are unnamed and immediately penetrate the superficial fascia to become subcutaneous. These veins are found outside the superficial fascia, in the subcutaneous tissue, on imaging.

Peripheral (caudal or below) to the takeoff of a large tributary vein, the GSV or SSV may dramatically decrease in caliber or may not be visible on DUS (Fig. 2). This may be an important observation to make because

incompetent truncal flow (usually in the GSV) can completely spill into a refluxing tributary, which then serves as the source of incompetence to a lower segment of the same truncal vein if they join again. If the intervening segment of the truncal vein can be traversed by a catheter, it may be possible to completely ablate both incompetent segments of the vein with a single access. However, if the vein segment between the incompetent segments cannot be traversed (or cannot be seen on DUS), complete ablation would probably require two punctures. In practice, most vein segments that are visible by ultrasound can be traversed with a guidewire (Fig. 3).

DIAGNOSTIC DUPLEX ULTRASOUND TECHNIQUE AND FINDINGS

The equipment required to perform the examination is relatively simple by current standards. Gray scale imaging, pulsed-wave Doppler (PWD), and a linear 7.5- to 10-MHz transducer are necessary elements that are found on most portable DUS units available today. Color Doppler (CD) can expedite the evaluation but is not required because PWD is a much more reliable and reproducible means of documenting reflux.

The goals of the DUS examination are to identify all incompetent truncal veins and to determine whether

Figure 1 Doppler ultrasonography (DUS) appearance of truncal veins. (A) Diagram of the thigh demonstrating the great saphenous vein (GSV) as seen on axial DUS. Note the intrafascial location of the GSV outside the muscular compartment. (B) DUS image of the thigh portion of the GSV. (C) Diagram of the small saphenous vein (SSV) at the level of the gastrocnemius muscles. (D) DUS image of the SSV at the level diagramed in (C).

Figure 2 Coronal depiction of three different pathways of incompetence, each imaged at two different locations with Doppler ultrasonography. (A) Incompetence confined to the saphenous trunks at the two levels imaged by ultrasonography would reveal an enlarged vein in the saphenous sheath at both levels. (B) Incompetence spills into a tributary vein, which is enlarged in the subcutaneous space in the lower of the two levels imaged. In this case the saphenous vein is visible but more normal in size at the lower imaging level. (C) Incompetence spills into a tributary vein, which is enlarged in the subcutaneous space in the lower of the two levels imaged. In this case the saphenous vein is not visible at the lower level. Invisible veins such as this are usually not traversable with a guidewire.

they are responsible for the patient's clinical problem. When evaluating patients for reflux, the examination should be performed in the pathophysiologically appropriate standing position. The patient is usually positioned on a stand to elevate the legs, which facilitates the performance of the examination. The patient is asked to turn the leg under examination outward to allow scanning of the inner thigh and calf (Fig. 4). Generally, the examination begins at the saphenofemoral junction (SFJ). The common femoral vein is evaluated for obstruction and reflux. Next, the GSV is followed from its junction down beyond the level of any visible varicose veins. The relationship of the GSV to any abnormal veins is assessed by tracing its course and the course of any tributaries that might lead to the abnormal veins. It is important to be aware of the standard tributary anatomy of the GSV and to recognize the frequent variations that are found.^{1,2} One particularly common variant is the anterior accessory GSV (AAGSV), which courses anterior to the path of the GSV. It has been described in the past as a long anterior circumflex vein or as a duplicated GSV. This vein takes origin from the GSV just below the SFJ and then courses obliquely down the anterior thigh. It is often responsible for anterior thigh varicose veins. It may rejoin the GSV in the lower thigh.

The caliber of the GSV is then assessed, as changes in caliber can provide important clues to physiologic disturbance. Normally, the vein is ≤ 4 mm in diameter. Veins > 7 mm have a high incidence of reflux. Reflux can occur in smaller veins but is usually clinically unimportant. Peripheral to the takeoff of incompetent tributary veins, the caliber of the vein often decreases. Conversely, the caliber of the GSV generally increases at the level of a significant incompetent perforator vein. A careful search should be made at points of GSV dilatation for this important source of reflux.

Any vein segment suspected of having reflux by size or by relationship to varicose veins is then evaluated with CD and PWD to visualize directly the direction of flow. Color is very helpful in quickly excluding reflux but can over- or underestimate its severity. All suspicious segments should be examined with PWD. Reflux can be easily documented by looking for antegrade flow followed by retrograde flow after a quick, firm compression of a peripheral segment of the GSV. Generally, when evaluating the GSV, compression of the calf should lead to augmentation of antegrade venous flow. When evaluating the AAGSV compression of the lower thigh is most useful. Upon release of compression, little if any retrograde flow should be noted. Reflux is documented when a significant amount of retrograde flow is found (Fig. 5). Although the criterion of ≥ 0.5 second of retrograde flow has been used to identify pathological reflux, several seconds of retrograde flow is typically seen in patients with incompetence.

Next, the patient is turned away from the examiner and the SSV is evaluated. The process of evaluation is similar to that of the GSV. This includes tracing the course of the SSV vein, assessing its size and its relationship to any varicose veins, and also assessing the popliteal vein. The anatomy of the SSV and its cephalic termination is quite variable. In ~ 50 – 70% of cases, the SSV terminates into the popliteal vein ~ 2 cm above the popliteal crease. However, more cephalad extension of this vein is common. Often it extends several centimeters up the posterior thigh to terminate in a perforating vein. Occasionally it extends even more cephalad toward the buttock crease before terminating into a perforating vein. A relatively common variant, the vein of Giacomini, is a connection between the GSV and the SSV. This vein runs subfascially in the posterior thigh and can be a pathway of incompetence leading to posterior thigh and calf varicose veins.³

Figure 3 Diagram of the pathways of reflux in a right lower extremity. Reflux begins at the saphenofemoral junction (SFJ) and extends down the great saphenous vein (GSV) to the thigh. At this point the reflux spills into a varicose tributary (point A). The incompetent tributary then refills the GSV at a lower level (point B) and leads to an additional segmental incompetence of the GSV. The GSV between the takeoff and reentry of the tributary is not incompetent. If this segment of GSV is visible to Doppler ultrasonography, it is probably traversable and a single access (near point C) may be all that is required for treatment of both the higher and lower segments. If this segment is not visible, two punctures are needed (near points A and C) to treat both incompetent segments of the GSV.

An evaluation of the femoral vein and the popliteal veins for reflux and obstruction should be included in the examination. If the patient does not have a history of prior deep vein thrombosis, an examination of the femoral and popliteal veins near their saphenous junctions is adequate to exclude significant deep vein obstruction.

In some cases, DUS in patients with varicose veins does not identify truncal vein incompetence. These nontruncal pathways are much more common in multiparous women and include pudendal and gluteal vein incompetence.⁴ Occasionally, these sources, especially the pudendal source, can lead to GSV incompetence more peripherally in the leg. Other important sources of nontruncal reflux include incompetent perforating veins

in the medial and lateral thigh and the popliteal fossa, which can usually be identified with DUS.

DUPLEX ULTRASOUND IN GUIDING SCLEROTHERAPY

DUS-guided therapy for venous disease began over 15 years ago with the introduction of US-guided sclerotherapy (UGS). UGS is currently used to direct sclerotherapy of deeper superficial veins and incompetent perforating veins. For some time there was a great deal of enthusiasm for UGS of the saphenous veins. However, high rates of recanalization reported by most investigators led to more cautious application of this technique. Recent interest in UGS with foam, both of incompetent tributary veins and of the saphenous trunks, may lead to greater utilization of this technique.

UGS combines the principles of sclerotherapy with the advantages of image guidance. Accurate identification of incompetent vein segments and distinction of these from adjoining normal veins and arteries improve the success and minimize the risk associated with sclerotherapy of deeper and larger veins. US guidance is first used to identify the target veins for therapy, which often cannot be identified with the naked eye. Once selected, the target vein can be punctured with real-time US guidance. This can be done longitudinally, but we find the transverse approach more useful. During injection, microbubbles in the sclerosant produce echoes that visibly confirm an intravascular injection. This phenomenon is more pronounced when foam sclerosants are used. After injection, successfully treated veins frequently go into spasm. Follow-up US several weeks after injection usually demonstrates noncompressible veins filled with trapped blood. The trapped blood usually resorbs over a several-month period, at which point the successfully treated vein becomes a cord that may be difficult to find with US.

DUPLEX ULTRASOUND IN GUIDING ENDOVENOUS THERMAL ABLATION

DUS-guided endovenous thermal ablation (EVTA) is an extension of the use of US to guide sclerotherapy. Laser and radiofrequency (RF) EVTA of the saphenous veins and their primary tributaries utilizes catheters peripherally inserted into the abnormal vein and advanced to the most central level of reflux. These catheters are then activated and withdrawn across the segment to be treated. The goal of these therapies is to occlude the incompetent vein segments permanently.^{5,6}

DUS is used first to identify the location for venous access. This is generally at the lowest or most peripheral level of the primary incompetent segment. Typically, the GSV refluxes from the groin down to the upper calf, where its incompetent flow spills into a

A

B

Figure 4 Photographs of a Doppler ultrasound examination being performed to evaluate the superficial venous system for incompetence. The patient is examined in the standing position while elevated on a platform relative to the examiner. (A) Examination of the great saphenous vein with the knee pointed slightly laterally. (B) Examination of the small saphenous vein with the knee slightly bent.

tributary that in turn fills varicosities. In these cases, the access is at the level of the takeoff of this tributary. The GSV is usually small farther down the calf, and the size transition seen on ultrasonography guides the point of access to GSV. Occasionally, the puncture and treatment can be applied to tributaries that remain relatively straight and parallel to the course of the GSV. In this case, these so-called superficial accessory saphenous veins can be directly accessed at the most peripheral part of the straight segment.

After access, DUS is used to monitor the advance of the catheter to the highest level to be ablated. In the case of the GSV, this is usually the SFJ. With the laser technique of EVTA, a long sheath is usually inserted into the femoral vein and the laser fiber placed through it. The fiber and sheath are withdrawn together until the tip of the fiber is at or just below the point of communication with the deep system (often the SFJ) (Fig. 6). This is usually best done with a longitudinal projection. With the RF technique of EVTA, a short sheath is placed and the RF catheter inserted. The RF device can track over a wire. The device is advanced to the SFJ and its tines are exposed; the individual tines are visible with DUS and confirm the position of the end of the device.

The next step in EVTA is the delivery of tumescent anesthesia (TA). TA is performed with a dilute large-volume local anesthetic that is delivered into the

perivenous space of the vein to be treated. TA is used not only to make the procedure painless but also to insulate the vein from surrounding nerves, arteries, and the skin as well as to efface the lumen of the vein to maximize circumferential energy transfer to the vein wall. DUS guidance of the needle being used to inject the TA fluid into the perivenous saphenous sheath is essential to maximize the effectiveness and efficiency of its delivery. Successful TA results in a hypoechoic perivenous halo that obliterates the vein lumen from the puncture site to the highest end of the segment to be treated. After TA, the cephalad tip of the EVTA device (laser tip or RF probe) is usually very well seen to confirm its location.

Thermal ablation begins after DUS is used to confirm that the tip of the EVTA tool is at the desired starting point. During EVTA, DUS usually has no utility. Some operators perform DUS immediately following EVTA, but the TA and spasm have usually obliterated the lumen of the treated vein by this point.

DUS should always be done to evaluate the treated vein segments periodically after EVTA.^{5,7} This is generally done in the first few weeks after therapy, a few months later, and at yearly intervals. DUS should also be performed to evaluate for the cause of any recurrent varicose veins. In the first several weeks after therapy, the treated veins are either smaller or the same size as before treatment, with a thick wall and nearly

Figure 5 (A) Pulsed-wave Doppler (PWD) imaging of a venous segment is performed during and immediately after external compression of the extremity at a more peripheral location. PWD tracing during compression in competent (B) and incompetent (C) veins. Augmentation of flow toward the heart is seen in both instances (velocities mapped below the x-axis). However, upon release of external compression, flow directed toward the feet is seen in incompetent segments (velocities above the x-axis).

obliterated lumen (Fig. 7). There should be no flow in the entire treated vein segment. This should be distinguished from the appearance of a thrombosed vein, which in the first few weeks should appear as a central hypoechoic to moderately hyperechoic filling defect in a vein that is usually enlarged compared with the pretreatment diameter. Partially thrombosed veins may have some flow. After several months to a year, successfully treated vein segments are usually difficult to identify and significantly smaller than the vein prior to treatment and have no flow.^{5,7} Most treatment failures are evident in the first few weeks as either thrombosed vein segments that subsequently recanalize or veins that are unchanged compared with the preliminary examination. In our

Figure 6 Longitudinal view of the saphenofemoral junction (SFJ) during positioning of a laser fiber prior to endovenous thermal ablation. The left of the image is toward the patient's head. A thin arrow points to the tip of the laser fiber ~5–10 mm below the SFJ at the takeoff of the superficial epigastric vein. The (*) identifies the SFJ, FV the femoral vein, GSV the great saphenous vein, and SEV the superficial epigastric vein.

experience, most treatment failures are segmental, beginning at the SFJ and extending downward to the takeoff of an incompetent tributary. Below this level, the vein is often successfully treated.

CONCLUSIONS

DUS is an integral part of the modern evaluation and management of patients with SVI. Precise anatomic and flow mapping is required prior to planning treatment in all patients with varicose veins. Treatment with EVTA and occasionally sclerotherapy requires precise monitoring with DUS as well. All patients treated with ETVA should be observed with DUS for several months after the procedure to confirm its success. It is incumbent for

Figure 7 Axial image of the thigh great saphenous vein 4 weeks after endovenous thermal ablation. The vein is smaller in caliber than before treatment and has a thick wall and a small very hypoechoic lumen. This lumen had no flow when evaluated with Doppler ultrasonography.

all physicians involved in caring for patients with SVI to become facile with the use of DUS to care for their patients optimally.

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