ULTRASOUND ASSESSMENT AND MAPPING OF THE SUPERFICIAL VENOUS SYSTEM (CATEGORY A VERSION)

INTRODUCTION

The utilization of venous ultrasound has increased greatly beyond its early application for the detection of deep venous thrombosis. The superficial system is now commonly examined to assess competency in those patients with suspected venous insufficiency. Ultrasound evaluation of the superficial system is also essential prior to the use of these veins as a bypass conduit. Autogenous vein is the still the preferred conduit for lower extremity arterial bypass procedures. Saphenous vein is likewise commonly used for coronary artery bypass grafts. Lastly, creation of hemodialysis access fistulas yet another reason why the status of the superficial veins must be assessed.

Surgeons must gather as much information as possible about a conduit in order to best plan for a procedure. Characteristics such as diameter, patency, position and depth are some of the features assessed pre-operatively. All the information provided by ultrasound allows for the selection of the most optimal venous conduit. Variations in venous anatomy or patency may alter the planned surgical procedure as well as the surgical approach used. Having the knowledge of the position of a suitable vein will help to minimize the amount of surgical dissection required.

The following course will examine the ultrasound techniques used for the evaluation of the superficial venous systems. The anatomy of the great saphenous, small saphenous, basilic and cephalic veins will be reviewed. Scanning techniques, tips and diagnostic criteria will be presented.

SUPERFICIAL VENOUS ANATOMY

The Great Saphenous Vein

Several years ago, venous nomenclature was revised and standardized in an attempt to avoid some commonly confused terms within the medical community both in the United States and abroad. The great saphenous vein had previously been referred to as the greater or long saphenous vein. The small saphenous vein is now the correct name for the vein previous called the lesser or short saphenous vein. It is important for those performing the ultrasound as well as those reading the study to use the appropriate current terminology.

Anatomy textbooks often depict the great saphenous vein as a single dominant trunk beginning at the level of the medial malleolus and coursing cephalad slightly anterior on the calf near the tibia (Figure 1). It continues medially along the thigh and terminates into the common femoral vein. This is a common configuration but multiple variations have been observed. Ultrasound and venographic reviews have revealed complicated saphenous systems with multiple large tributaries.

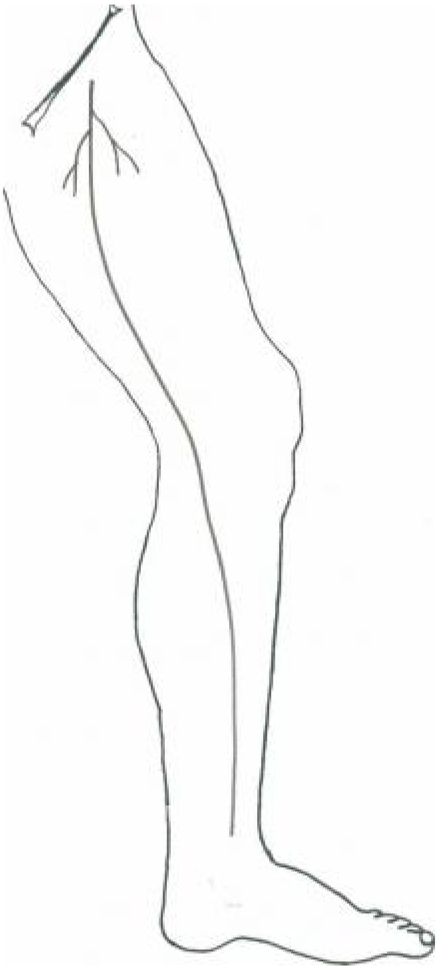

Figure 1. Typical anatomic configuration of the great saphenous vein with a single medial dominant system in the thigh and an anterior dominant system in the calf.
Click on image to enlarge

Figure 2 illustrates common configurations of the thigh portion of the great saphenous vein. In about 60% of cases, the great saphenous vein is a single medial trunk in the thigh, curving slightly toward the inner thigh. Less frequently in only 8% of cases there is a single dominant system in the thigh that courses laterally. It is thought that this lateral version is more likely the anterior accessory saphenous vein which has become the dominant outflow track in these instances. Remaining configurations of the great saphenous vein all include various interconnections with tributaries. Some of the larger tributaries appear to create a double saphenous system or a partial closed loop. The major tributaries of the great saphenous vein include the anterior and posterior accessory saphenous veins.

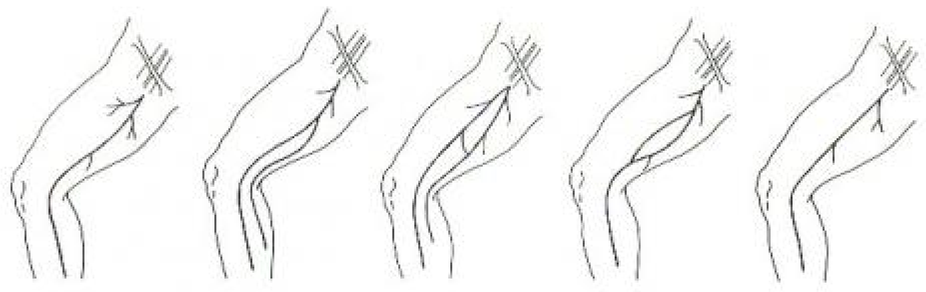

Figure 2. Anatomic variations in the configuration of the thigh portion of the great saphenous vein. *Click on image to enlarge*

It is very important to identify the various veins that are present. Surgeons can select the most appropriate vein based on the planned procedure. If a short segment of vein is needed, a tributary or accessory saphenous vein may be used, thus maintaining the main trunk of the great saphenous for use if needed at a later date.
The great saphenous vein in the calf is less variable and in two-thirds of cases is a single dominant system coursing anteriorly near the medial border of the tibia (Figure 3). The posterior accessory saphenous vein discussed in the preceding section is also present in the calf. It typically has a smaller diameter as compared to the main trunk of the saphenous vein and is not suitable for use as a bypass conduit. In about 7% of patients, the posterior accessory saphenous vein is dominant over the more anterior system of the calf.

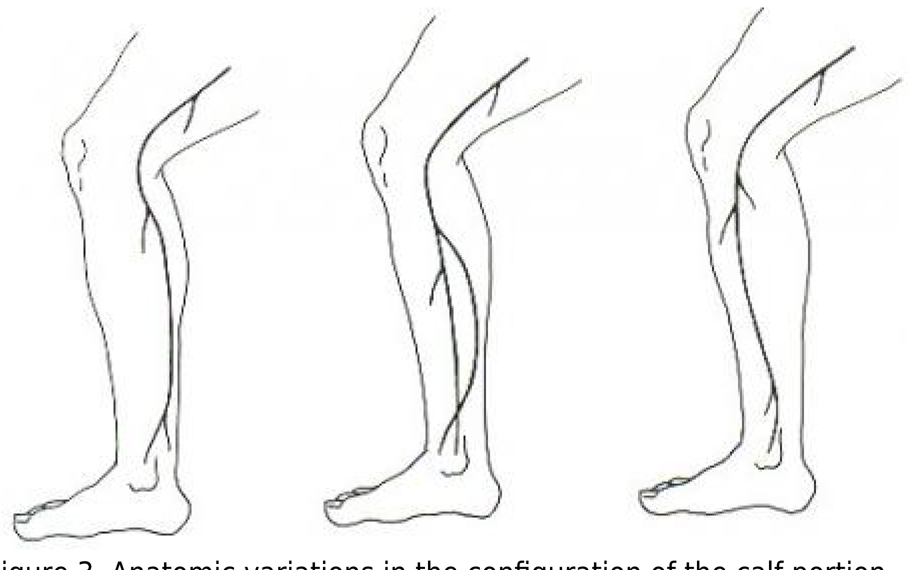

Figure 3. Anatomic variations in the configuration of the calf portion of the great saphenous vein. *Click on image to enlarge*

When using the vein as a conduit for a lower extremity bypass, the locations of the perforating veins should be identified. Perforating veins connect the superficial venous system to the deep venous system (Figure 4). They have valves to insure the one-way direction of blood flow from the superficial to the deep. If the vein is used insitu for a bypass and a perforating vein is left intact, blood flow will be shunted away from the distal bypass to the deep venous system thus creating an arteriovenous fistula. This arteriovenous fistula will steal blood from the distal arterial bed and will need to be ligated in order to maintain adequate flow through a bypass. Marking the locations of perforating veins during the preoperative mapping procedure will alert the surgeon to allow for ligation of the perforators prior to the completion of the bypass surgery.

Figure 4. A grayscale image of a perforating vein coursing between the great saphenous vein and the deep system.
Click on image to enlarge

The Small Saphenous Vein

Another source of conduit is the small saphenous vein. It can be used for lower extremity arterial bypass procedures and rarely for coronary artery bypassgrafts. The small saphenous vein begins at the junction of two small veins which leave the foot and travel medially and laterally adjacent to the Achilles tendon. The small saphenous vein courses as a single trunk approximately at the middle of the posterior aspect of the calf. It terminates at the popliteal fossa into the popliteal vein. In approximately 20% of limbs, the small saphenous vein extends above the popliteal fossa. This portion of the vein is referred to as the cranial extension of the small saphenous vein. This cranial extension can terminate directly into the femoral vein, or into the inferior gluteal vein or may communicate into the great saphenous vein. This cranial extension of the small saphenous vein is important when a patient may be vein limited and a long length of vein is needed as a conduit.

The Cephalic and Basilic Veins

Venous mapping techniques includes the evaluation of the superficial veins of the arm. It is the standard of care to assess these veins in patients undergoing the creation of a dialysis access fistula. The cephalic vein begins at the level of the wrist, continuing along the radius in the forearm, through the upper arm, terminating into the subclavian vein. The basilic vein also begins at the level of the wrist, coursing along the ulnar aspect of the forearm. The basilic vein continues into the upper arm where it joins the brachial veins to form the axillary vein. The termination of the basilic vein can vary and in about one-third of patients the basilic vein terminates in the mid or lower portion of the upper arm rather than closer to the axilla. The cephalic and basilic veins communicate at the antecubital fossa via the medial cubital vein. The patterns of the venous segments at the antecubital fossa and the position of the medial cubital vein can display variability.

Examination Preparation

The ultrasound equipment should be optimized to provide a well-defined near field image. Focal zones should be adjusted to maximize the resolution of the near field. A high frequency ultrasound transducer of at least 10 MHz should be used but occasionally lower frequencies are needed to image deeper veins in obese individuals.

The position of the veins can be marked on the skin surface creating a map that can be helpful during surgery. Various marking devices can be used including surgical skin markers, other types of permanent markers and liquid permanent ink. Since the various inks used can be messy, it is recommended to cover the ultrasound transducer with a nonsterile probe cover. Sparingly use the ultrasound gel to allow for easier skin marking.

Patient position is very important particularly when dealing with small diameter veins. The patient's limb should be placed in a dependent position to maximize the pressure in the superficial veins. For the mapping the leg veins, the patient should be placed in a reverse Trendelenberg position with the hip externally rotated and knee slightly flexed (Figure 5).

Figure 5. Patient position for mapping of the great saphenous vein.
Click on image to enlarge

This position provides adequate access to the entire length of the great saphenous vein. A lateral decubitus position can be used for assessment of the small saphenous vein (Figure 6).

Figure 6. Patient position for mapping the small saphenous vein.
Click on image to enlarge

Rarely is it necessary for the patient to stand in order to adequately visualize and measure the superficial veins of the leg. The arm veins can be examined with patient's arm extended out to the side and slightly lower than the chest level (Figure 7). Tourniquets can be used to aid in dilating the veins. However, they are not required and often produce too much patient discomfort.

Figure 7. Patient position for mapping the superficial veins of the arm.
Click on image to enlarge

Lastly the examination room should be kept warm in order to limit vasoconstriction. Keep areas of the patient not being examined covered to aid in keeping the patient warm. Keeping the foot covered of the leg being examined is also helpful in reducing vasoconstriction.

MAPPING PROTOCOL

Given the superficial veins are under low venous pressure, light transducer pressure should be used. Using a transverse orientation, the great saphenous vein is identified at the saphenofemoral junction (Figure 8).

Figure 8a. illustrates the transverse orientation used at the groin to identify the saphenofemoral junction. *Click on image to enlarge*

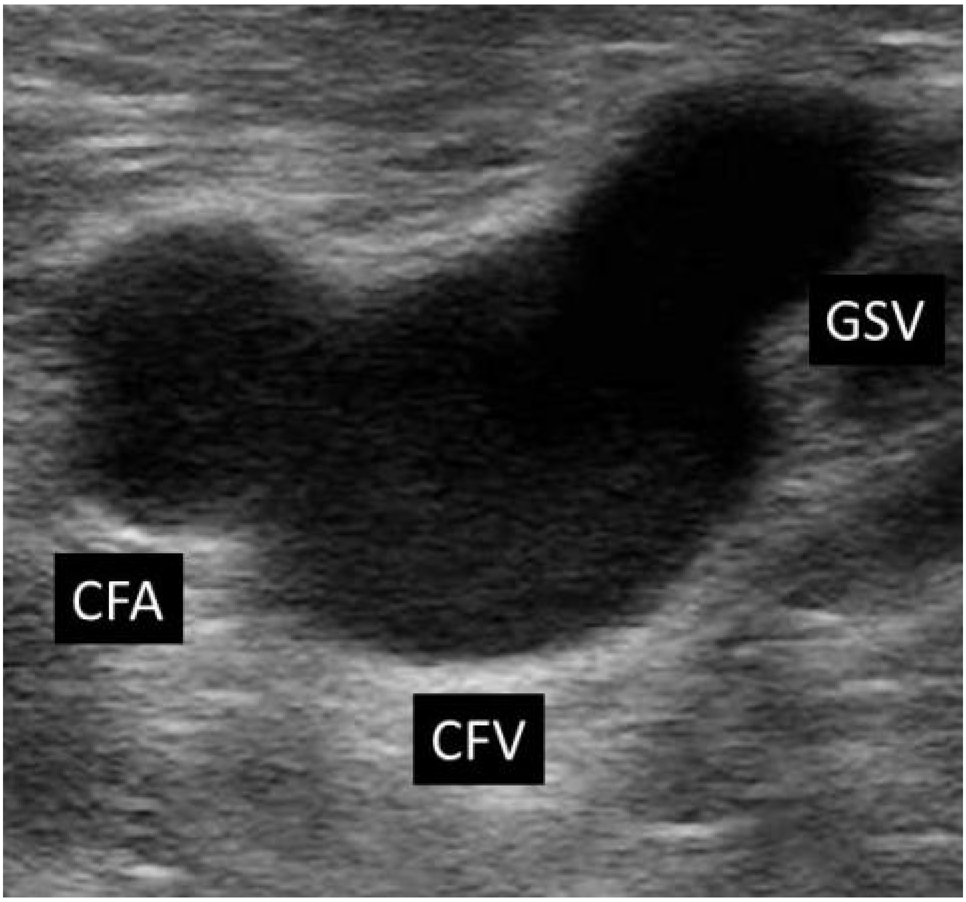

Figure 8b. is the corresponding ultrasound image at this level.
Click on image to enlarge

Either a longitudinal or transverse transducer orientation can be used to follow the line of the vein and map its course. With a longitudinal approach, the vein should appear to completely fill the screen from right to left. The transducer should be perpendicular to the skin surface. These techniques will assure the vein is not being imaged obliquely but correctly being examined. A small mark is placed in front of the ultrasound transducer along the narrow edge of the transducer (Figure 9).

Figure 9. The proper position of the transducer in a longitudinal axis and placement of the skin mark. *Click on image to enlarge*

If a transverse approach is used, the vein should appear circular and centered on the ultrasound screen. A skin mark is then placed exactly at the center of the long face of the transducer (Figure 10). After the initial skin mark is placed, the transducer is moved slightly distally keeping the vein in the center of view placing a new mark every 2-3 centimeters. This procedure is continued to the level of the ankle.

Figure 10. The proper position of the transducer in a transverse axis and placement of the skin mark.
Click on image to enlarge

Once the main course of the great saphenous has been mapped, the saphenofemoral junction is again identified using a transverse orientation. Using the preliminary marks as a guide and remaining transverse to the vein, the main system is followed in order to identify large tributaries and measure the vein diameter. Two types of tributaries will be identified including veins which course superficially (Figure 11) and deep perforating veins (Figure 4). Each should be marked at the level they terminate into the main system. It is especially important to follow all large tributaries in order to identify partial loops or double systems.

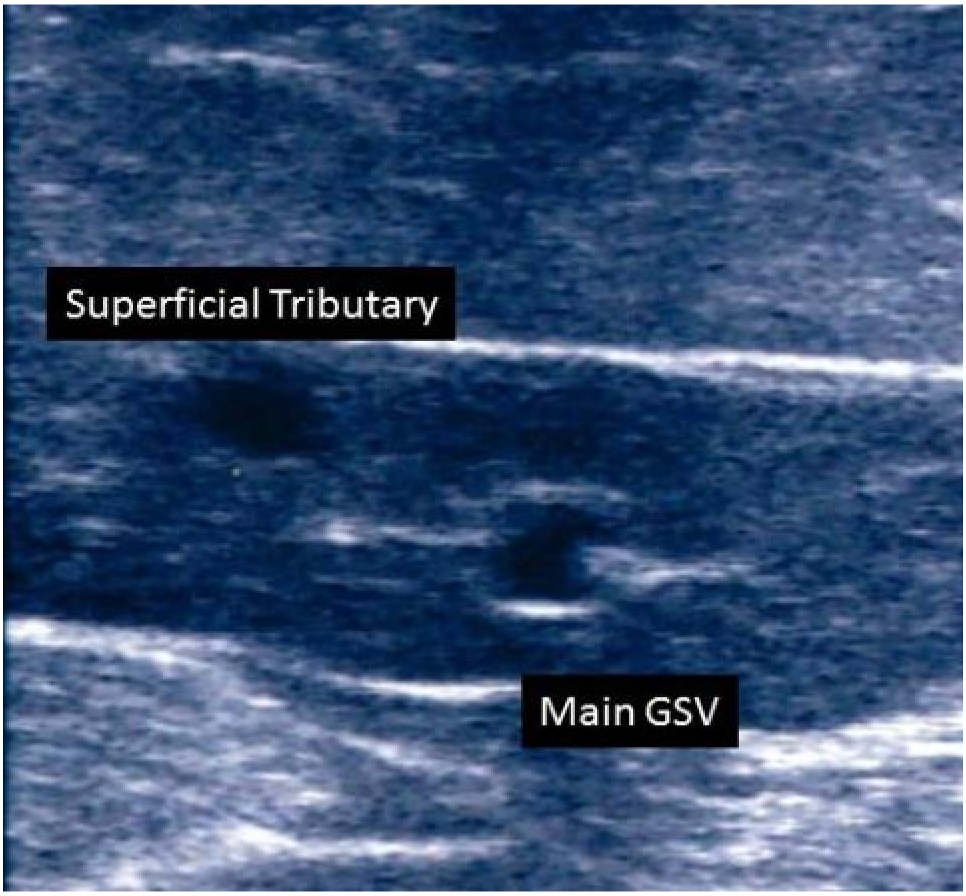

Figure 11. An ultrasound image of a tributary of the great saphenous vein which courses superficially. *Click on image to enlarge*

Saphenous vein diameter is measured at multiple levels including the saphenofemoral junction, proximal, mid and distal thigh, knee and proximal, mid and distal calf. If multiple systems exist, each should be measured to determine system dominance. The diameter is measured by the placing calipers perpendicular to each other at the outer to outer walls (Figure 12).

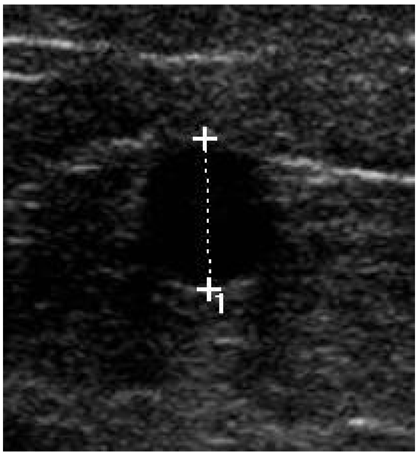
Figure 12. Illustration of caliper placement for measurement of saphenous vein diameter.
Click on image to enlarge

Once the course of the vein has been marked, the tributaries have been noted and the vein diameters measured, the ultrasound gel can be wiped off the limb. Liquid marking ink (such as a carbol fuchsin stain used in radiation therapy) can be applied with a cotton-tipped applicator or a permanent marker can be used. The dashed marks originally placed are connected to map the course of the vein (Figure 13). This skin marking will remain on the skin for varying lengths of time depending on the type of permanent ink used. In most patients, the marks will be visible for at least 3-5 days. In addition, a hard copy drawing is recorded for the patient's chart.

Figure 13. A patient leg with a completed great saphenous mapping. *Click on image to enlarge*

The scanning techniques described for the great saphenous vein can be used to map the small saphenous, cephalic and basilic veins. The small saphenous vein is first identified at its confluence with the popliteal vein then followed distally through the calf (Figure 14). The small saphenous vein diameters are recorded in the proximal, mid and distal calf. Figure 15 illustrates a completed small saphenous vein mapping.

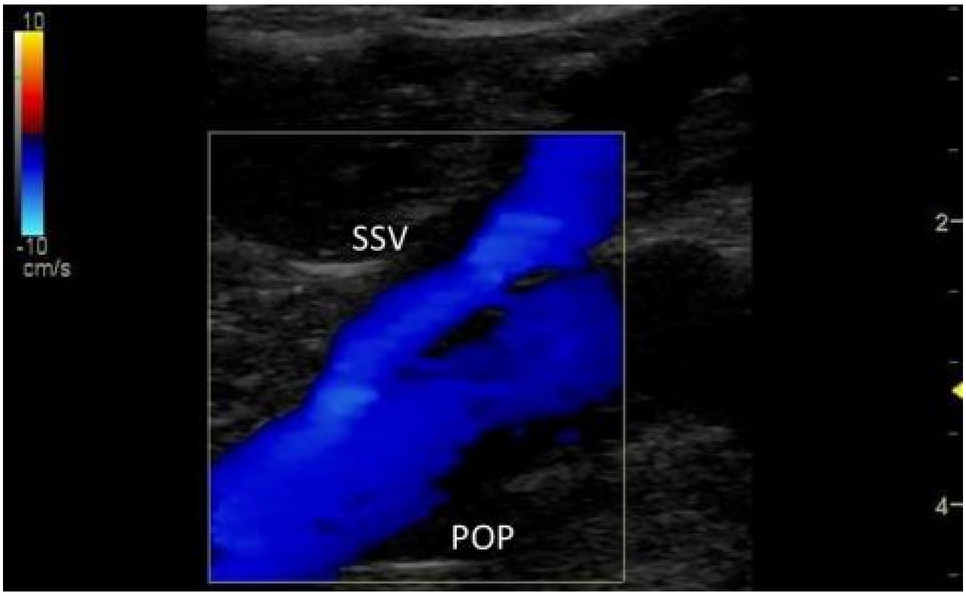

Figure 14. An ultrasound image of the small saphenous vein as it terminates into the popliteal vein. *Click on image to enlarge*

Mapping of the basilic vein is performed by following the vein along the ulnar aspect of the forearm to its termination into the axillary vein. The cephalic vein can be followed from the radial aspect of the forearm to the upper arm. In the upper arm if courses over the biceps muscle, across the shoulder terminating into the subclavian vein. In patients getting vein mapping prior to creation of hemodialysis access fistulae, the position of the medial cubital vein as it relates to the cephalic and basilic veins is mapped. The vein diameters are measured proximally and distally in the forearm and upper arm. Figure 16 illustrates a completed arm vein mapping.

Figure 15. A patient leg with a completed small saphenous vein mapping. *Click on image to enlarge*

Figure 16. A patient arm with a completed mapping of the cephalic and basilic veins.
Click on image to enlarge

DIAGNOSTIC CRITERIA

Vein mapping must determine much more than the presence of absence of a vein. It must also determine the suitability of that vein for use as a bypass conduit. A normal healthy vein should have smooth, thin walls (Figure 17). The vein should be compliant and easily compress with minimal transducer pressure. Valve sinuses may appear elliptical but in some smaller veins they may be difficult to identify. If valve leaflets are visualized, they should be freely moving without any evidence of thrombus behind the leaflets.

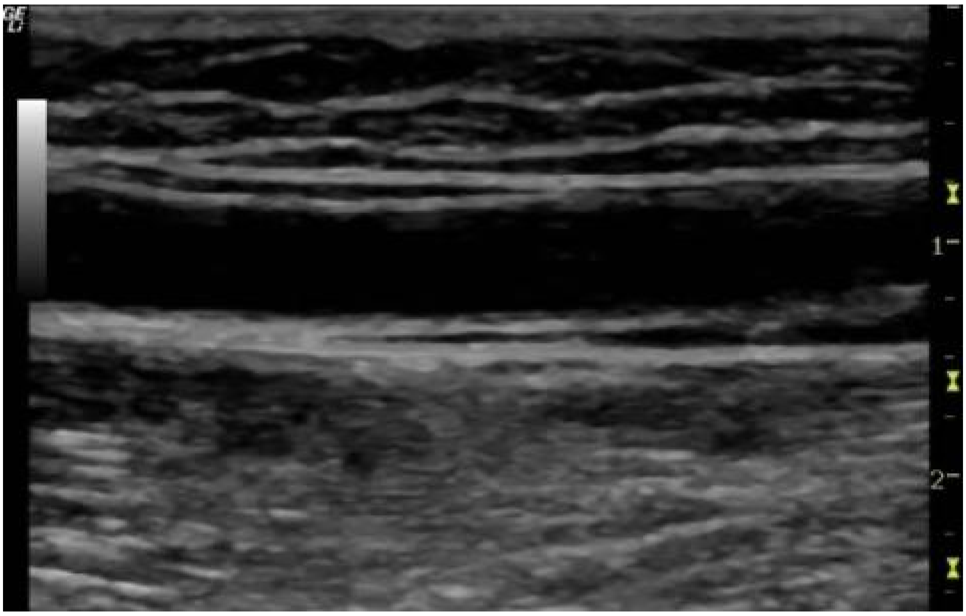

Figure 17. An ultrasound image of a normal healthy vein with smooth, thin walls. *Click on image to enlarge*

The planar arrangement of the veins should be observed during the mapping procedure and noted on the written report. This is of particular importance with mapping the great and small saphenous vein as the depth of these vessels will vary. Figure 18 illustrates the normal orientation of the main trunk of the great saphenous vein within the saphenous compartment bounded by the saphenous fascia superficially and deeply by the muscular fascia. These layers of fascia produce the appearance of what some people refer to as the Egyptian eye appearance of the vein.

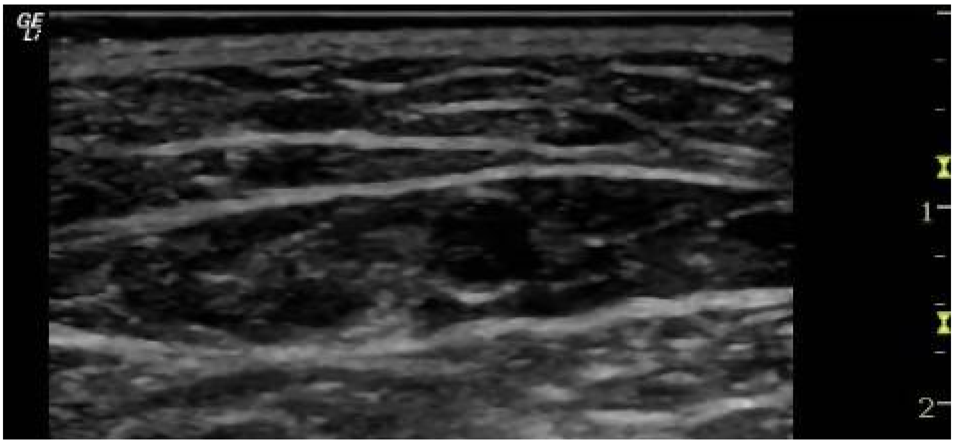

Figure 18. A transverse view of the great saphenous vein within the saphenous compartment. *Click on image to enlarge*

When double systems exist, often the veins travel in different anatomic planes through the thigh as shown in Figure 19. The dominant vein may not be the most superficial system or not be within the saphenous compartment. This information is important to the surgeon so that the best vein is selected.
When double systems exist, often the veins travel in different anatomic planes through the thigh as shown in Figure 19. The dominant vein may not be the most superficial system or not be within the saphenous compartment. This information is important to the surgeon so that the best vein is selected.

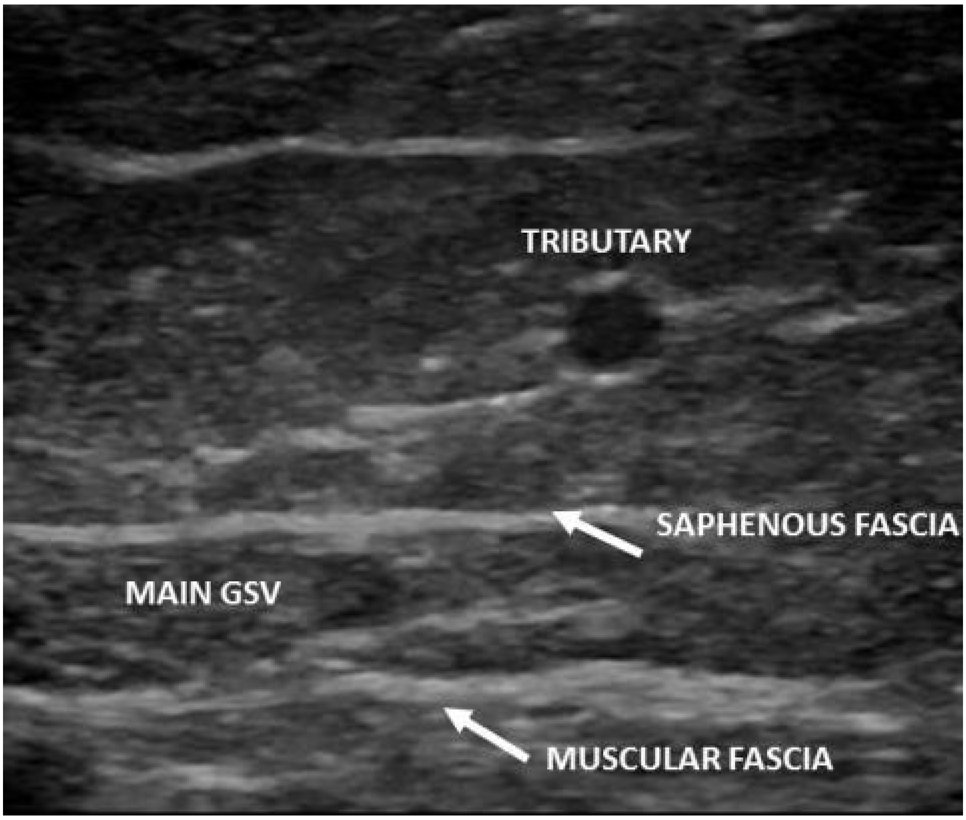

Figure 19. A transverse view of the great saphenous vein and a tributary outside the saphenous compartment.
Click on image to enlarge

Laboratory criteria for suitable vein diameters vary based on surgeon preference and the procedure performed. A cardiothoracic surgeon may prefer a certain diameter vein for a coronary bypass while a general surgeon may have different diameter criteria for a dialysis fistula. Most surgeons will not use a vein which is less than 2.0 mm in diameter.

Various abnormalities can be observed within the superficial veins. Isolated segments of partial thrombus may be encountered during vein mapping (Figure 20). Thrombus will vary in echogenicity with an anechoic or hypoechoic appearance being more likely associated with acute thrombus. Chronic or residual thrombus may be hyperechoic but this is less reliable. Completely thrombosed veins will be noncompressible, lack any color filling and not demonstrate a Doppler signal. With partially thrombosed veins, the walls may slightly compress together under transducer pressure but not completely coapt. Color flow imaging will demonstrate a reduced flow lumen. Doppler signals obtained from partially thrombosed veins will display a decrease in phasicity.

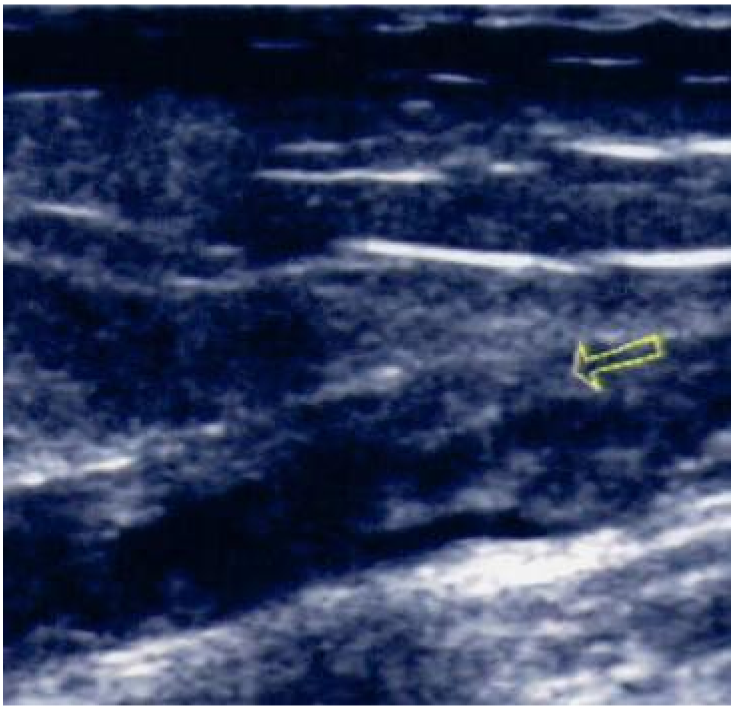

Figure 20. An ultrasound image of a saphenous vein with thrombus within it. *Click on image to enlarge*

Varicose segments will appear as dilated, tortuous portions of the saphenous system. The visible presence of varicosities during a physical examination are not an automatic contraindication to saphenous vein mapping. In many patients, the varicosities are tributaries off the main trunk (Figure 21). The main system of the saphenous vein in these patients can be often found in the normal subfascial plane. It may not be dilated and thus suitable for use in bypass procedures.

Figure 21. Varicose tributaries off the great saphenous vein.
Click on image to enlarge

An irregular intimal surface or wall thickening may indicate evidence of recanalization (Figure 22). These veins are not usually considered to be adequate conduit for arterial bypasses. Occasionally calcification can be observed in the absence of any other abnormality. Bright echoes within the vein wall producing acoustic shadowing is the classic ultrasound appearance of calcification (Figure 23). Isolated areas may not preclude the entire vein from being used as a conduit. The surgeon may simply use non-calcified segments. However, diffuse intermittent calcification renders the vein inadequate for bypass material. Venous calcification can be often observed in diabetic patients. Lastly, another pathology that can be noted on the image is a stenotic or frozen valve (Figure 24). This may be encountered in a vein that was previously thrombosed.

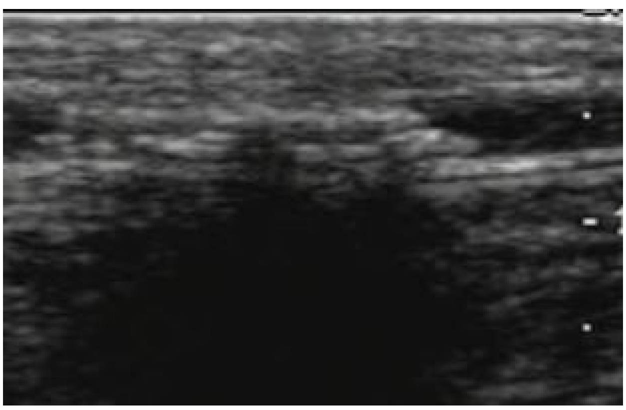
Figure 22. An ultrasound image of a thickened

recanalized vein. *Click on image to enlarge*

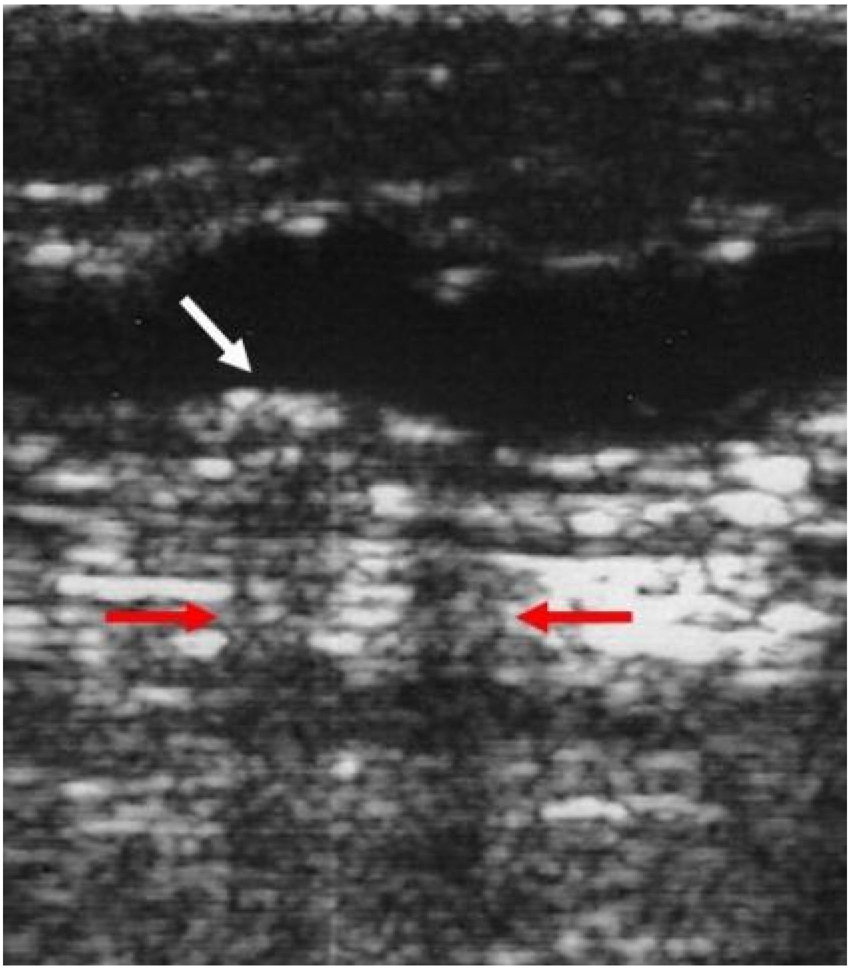

Figure 23. An ultrasound image of calcification in the saphenous vein wall. The white arrow is indicated the calcification in the vein wall. The red arrows indicate the acoustic shadowing produced by the calcification.
Click on image to enlarge

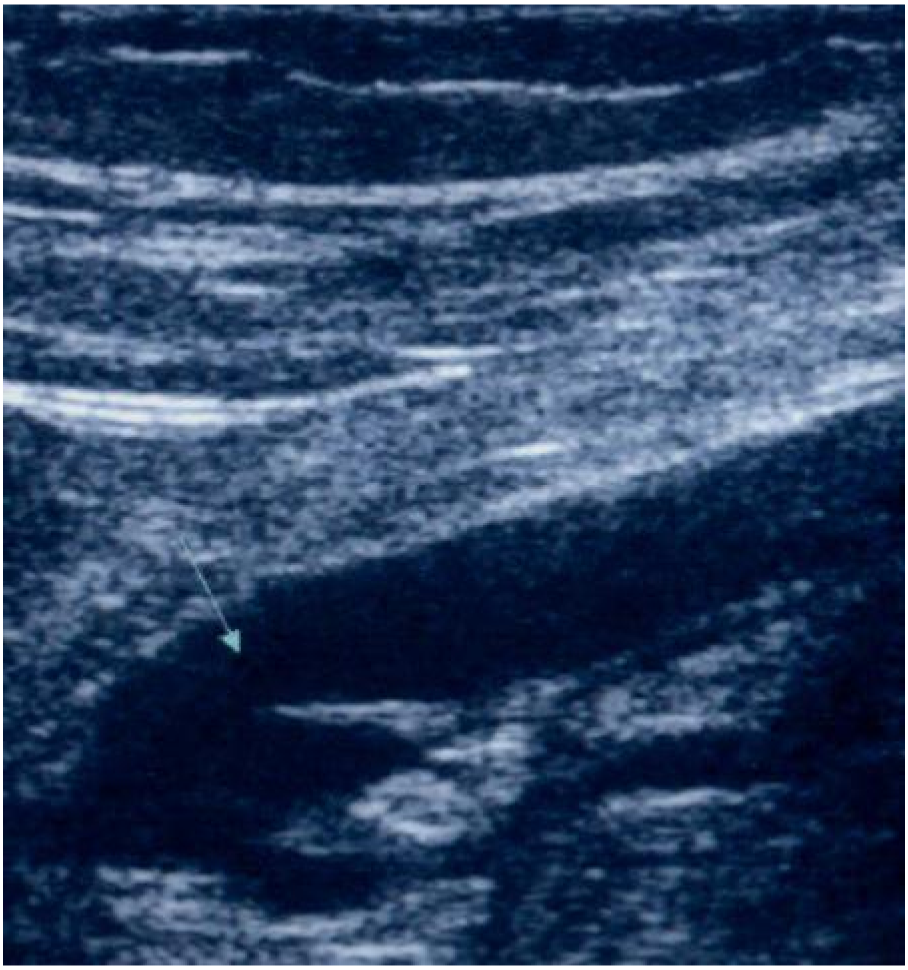

Figure 24. An ultrasound image of frozen valve leaflet.
Click on image to enlarge

REFERENCES

1. Caggiati A, Bergan JJ, Gloviczki P, et al. nomenclature of the veins of the lower limbs: An international interdisciplinary consensus statement. J Vasc Surg 2002; 36:416-22.
2. Kupinski AM. Ultrasound evaluation and mapping of the superficial venous system. In Diagnostic Medical Sonography: The Vascular System, Kupinski AM (ed). Lippincott, Williams & Wilkins, Philadelphia, 2013, pp.245-260.
3. Kupinski AM, Evans SM, Khan AM, et al. Ultrasonic characterization of the saphenous vein. Cardiovasc Surg 1993; 1:513-517.
4. Leopold PW, Shandall AA, Kupinski AM, et al. The role of B-mode venous mapping in infrainguinal arterial bypasses. Brit J Surg 1989; 76:305-307.
5. Shah DM, Chang BB, Leopold PW, Corson JD, Leather RP, Karmody AM. The anatomy of the greater saphenous venous system. J Vasc Surg 1986; 3:273-283.