The valves and tributary veins of the saphenofemoral junction: ultrasound findings in normal limbs

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Abstract

In the past the saphenofemoral junction (SFJ) for the surgeon was regarded as a simple conduit to be obliterated. With modern ultrasound we can distinguish the components of this complex structure and examine their haemodynamic function and suggest more haemodynamically-focused interventions. Despite this, there are no ultrasound studies describing the components of the normal SFJ and their haemodynamic significance. Patients attending our vascular laboratory with suspected deep vein thrombosis were screened and the SFJ in 75 limbs with no physiological or haemodynamic abnormalities were examined. The terminal (TV) and preterminal (PTV) valve morphology and the distance from the SFJ were assessed. The number of tributaries and their position relative to these valves was also examined. TV and PTVs were identified on ultrasound in all 75 limbs. TVs were found at a mean distance of 0.4 cm (range 0–1.2 cm) from the SFJ. Nearly a third of all limbs had at least one tributary vein identified superior to the TV. The greater the distance to the TV, the greater the number of tributary veins one should expect to find superior to the TV. PTV location was more variable. PTVs were identified at a mean distance of 3.1 cm (range 0.4–8.7 cm), giving rise to a large number of configurations of tributary veins in the intervalve space. This study characterizes the ultrasound appearances of the normal SFJ and compares these with reported anatomical studies. Valves can be consistently identified whereas the number and location of the tributaries are very variable. This should inform planning of haemodynamically-focused treatment at the SFJ.

Introduction

The saphenofemoral junction (SFJ) has at times been regarded as a relatively simple conduit and treated as such in traditional ablative interventions. With the increased resolution of modern ultrasound, it has become possible to view, in real time, the valves, tributaries and the associated structures of the SFJ and assess their function. This has resulted in a new way of understanding its function. In contrast to traditional thinking, it may be more appropriate to consider the SFJ as a sophisticated multi-part structure comprised of the arch of the great saphenous vein (GSV), terminal and preterminal valves (TV and PTV), plus a number of tributary veins.[1] A normal SFJ relies on the integrated functioning of each of the component parts. Consequently, the TV and PTV has become the subject of increasing interest as their integrity may ultimately determine the function of the entire GSV. Loss of function at these valves has been associated with retrograde flow and according to the long held descending theory of valve failure, led to the development of varicose veins.[2] Other evidence would suggest antegrade progression of valve incompetence is more likely with eventual failure of the TV and PTV.[3]

The nomenclature of the valves of the SFJ has not been without difficulty. An awareness of the importance of the most proximal and second most proximal valves of the GSV has been seen in the literature since Pichot *et al.*[4] The terms subterminal valve[4,5] and preterminal valve[6,7] have been used interchangeably to describe the second most proximal GSV valve. There are further variations in the use of this terminology. A report by Muhlberger[6] was criticized by Caggiati[8] for reporting the absence of TVs in circumstances where the TV was located distal to one or more GSV superficial tributary veins and also other inaccuracies when the PTV is located proximal to other superficial tributaries. Given the highly variable nature of the SFJ and its tributary veins, it is no wonder there is confusion as to the use of this nomenclature. More relevant is the relative hemodynamic significance of these variations.

The implications of the haemodynamic impact of each component of the SFJ has lead to alternative treatments for varicose veins, which are focused on treating the dysfunctional components and sparing those that are not.[9] It has called into question the traditional understanding and approaches to treatment of SFJ reflux. Total obliteration of the SFJ, as the previous gold standard, has been challenged. Limited interventions that preserve normal venous drainage from superficial tributary veins such as the superior epigastric or pudendal veins may help reduce the high rates of recurrence associated with traditional vein stripping.[9]

Much of the evidence regarding the architecture of the SFJ comes from studies of the abnormal SFJ before and after treatment, and evidence is sparse regarding studies in the normal subject. Anatomical cadaver studies of normal limbs have been carried out, but the authors of such studies[6] note a need for ultrasound investigations of the SFJ in normal limbs to inform the debate. Our study aims to characterize the functional anatomy and relationship of the valves and major superficial tributaries of the SFJ in normal limbs in the absence of reflux.

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Materials and Methods

Subjects

For a five-month period all subjects attending our Vascular Diagnostics clinical laboratory for venous assessment for suspected deep vein thrombosis (DVT) were screened to select limbs with normal venous system including a normal (non-refluxing) SFJ, superficial and deep systems, and clinical absence of venous disease. Subjects were excluded from further study also for technical reasons such as body habitus, lack of mobility, inability to be tilted or to complete an adequate valsalva maneuver.

Ultrasound imaging

Detailed duplex ultrasound examination

was carried out to evaluate the morphology and distance of the terminal and preterminal valves from the SFJ, and the number and relationship of tributary vessels to these valves. All measurements were taken from the SFJ to the attachment site of the respective valve. The TV was defined as the most proximal valve of the GSV. The PTV was defined as the second most proximal valve of the GSV. Patients were scanned with either an ATL 5000 scanner (Phillips Medical Systems, Eindhoven, Netherlands) or at later dates with a Toshiba Aplio XG scanner (Toshiba Medical Systems, Tokyo, Japan). A 12–12.5 MHz linear array probe with colour and spectral Doppler modalities was used to visualize the SFJ in long section and trans-section in the 35° reverse Trendelenburg position. Colour and spectral Doppler imaging was used to demonstrate reflux in limbs that were excluded, while B-Mode imaging only was used when imaging structures of interest to maximize the spatial and contrast resolution when dealing with these small structures.

During the valsalva maneuver, the subject was asked to blow into their cheeks and tense their abdominal muscles until spectral analysis at the common femoral vein (CFV) showed abolishment of the normal phasic antegrade flow. The prevailing international standards of retrograde flow duration <1 s at the CFV and <0.5 s elsewhere in the limb were considered normal.10 The patient was asked to practice this maneuver until the sonographer was certain that they understood it fully and could reproduce it correctly when asked.

Analysis

All statistical analysis was carried out using Statview version 5.0.1 (SAS Institute Inc., Cary, NC, USA). Significance was $P<0.05$, continuous variables were analyzed by calculating the mean, range and using a box plots. The nominal variables were assessed using Kruskal-Wallis analysis.

Results

A total of 221 limbs were screened, of whom 75 were eligible. The remaining 146 limbs were excluded due to: incompetent SFJ and/or GSV (54); unfavorable habitus (18); DVT and/or superficial thrombophlebitis (17); technical difficulties (28); absent SFJ and/or GSV (17); deep system reflux (2); other (10). There were 30 males and 45 females with a mean age of 59.

Terminal and preterminal valves were identified in all 75 included limbs (Figures 1 and 2). Seven limbs initially appeared to have monocuspid terminal valves (Figure 3) and were reassessed on a subsequent occasion. Of these, five were found to be bicuspid. In these limbs the leaflet attached to the anterior vein wall was difficult to visualize due to artifactual echo signals generated by the venous wall being erroneously represented in the anechoic lumen and also the echogenicity of slow moving erythrocytes at the margin of the lumen. The other two limbs had one dominant valve leaflet and one degraded valve leaflet (Figure 3). Despite this, they did not demonstrate significant reflux at the CFV or the GSV.

The TVs were identified at a mean distance of 0.41 cm from the SFJ (range of 0 cm to 1.24 cm). In 20 out of the 75 limbs (27%) the TV was recorded less than 0.1 cm from the SFJ, with 18 of these having the TV exactly where the GSV connects with the CFV. The mean distance to the PTVs was 3.06 cm (range 0.43 cm to 8.71 cm). Very few PTVs were identified closer than 1.3 cm to the SFJ. All but 7 (9%) were identified at distances greater than this. The mean distance between terminal and PTV was 2.6±1.3 cm.

The identity and sources of tributaries and their confluences about the normal SFJ were often difficult to follow because of low volume of flow and smaller size compared to that seen in incompetent systems. Consequently naming each tributary was inconsistent and therefore was not included in this study. In 22 out of 75 limbs (29%), one or more tributary vessels were observed between the SFJ and the TV (Figure 4). Twenty-one of these limbs possessed one tributary, while one limb had two tributaries identified. Most limbs (74, 99%) had at least one tributary vessel identified between the terminal and preterminal valve. The maximum total number of tributaries identified was four, which was demonstrated in only three limbs (4%). In one limb no tributaries were identified (1%).

The greater the distance to the TV the greater the number of tributary veins found superior to the TV. A similar relationship appeared to exist for the length of the inter-valve segment (Figure 5) but the significance of this was not confirmed following Kruskal Wallis analysis, (P=0.57).

Figure 1. Brightness mode (B mode) ultrasound image of the saphenofemoral junction. Measurements were made from the deep valve leaflet attachment site, to the point where the great saphenous vein (GSV) joined the common femoral vein (CFV) and from the terminal valve to the preterminal valve. (A) The point where the GSV tributaries with the CFV where all measurements were taken from. (B) Bicuspid terminal valve (TV) leaflets. (C) Bicuspid preterminal valve leaflets (PTV).

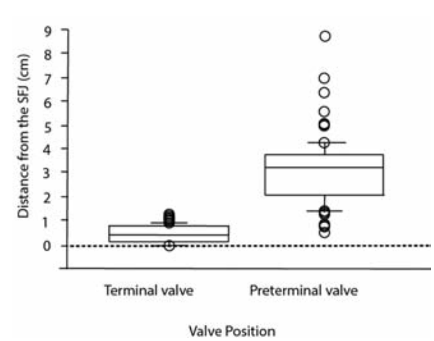

Figure 2. Distance (cm) from the saphenofemoral junction (SFJ) to the terminal and preterminal valves. Plot showing lower quartile, median and upper quartile (n=75).

Discussion and Conclusions

The debate about the significance of the valves located in the saphenous arch of the GSV remains relevant today. While Mühlberger[6] described the relationships of these valves in normal cadavers and Cappelli[1] did so with ultrasound in limbs with venous disease, both these authors point out the need for studies in normal ambulant limbs. We agree that this is required to make any inferences regarding the importance of these valves in the development of venous disease and its treatment. This study has described the ultrasound features of these valves and their relationship to tributaries in the normal great saphenous arch in 75 normal legs.

The valves of the SFJ are small very fine structures that require high frequency ultrasound to visualize them accurately enough to determine valve morphology. With the trade off between ultrasound penetration and resolution, there were a significant number of subjects who were unsuitable for the study because of habitus and related technical reasons. A large number of subjects (146) were excluded from this study, leaving a smaller but sizeable population in which imaging was technically excellent. While it is unlikely that the excluded limbs would be drastically different this cannot be discounted and this may limit the application of this data to similar subjects. While this cohort was selected from those attending a vascular laboratory service, the limbs studied were functionally and physiologically normal and we believe they are representative of the normal situation. Even in these selected limbs, it was still at times difficult to image the terminal valves, more specifically the superficial leaflet of the TV. This lead to some repeated examinations to confirm

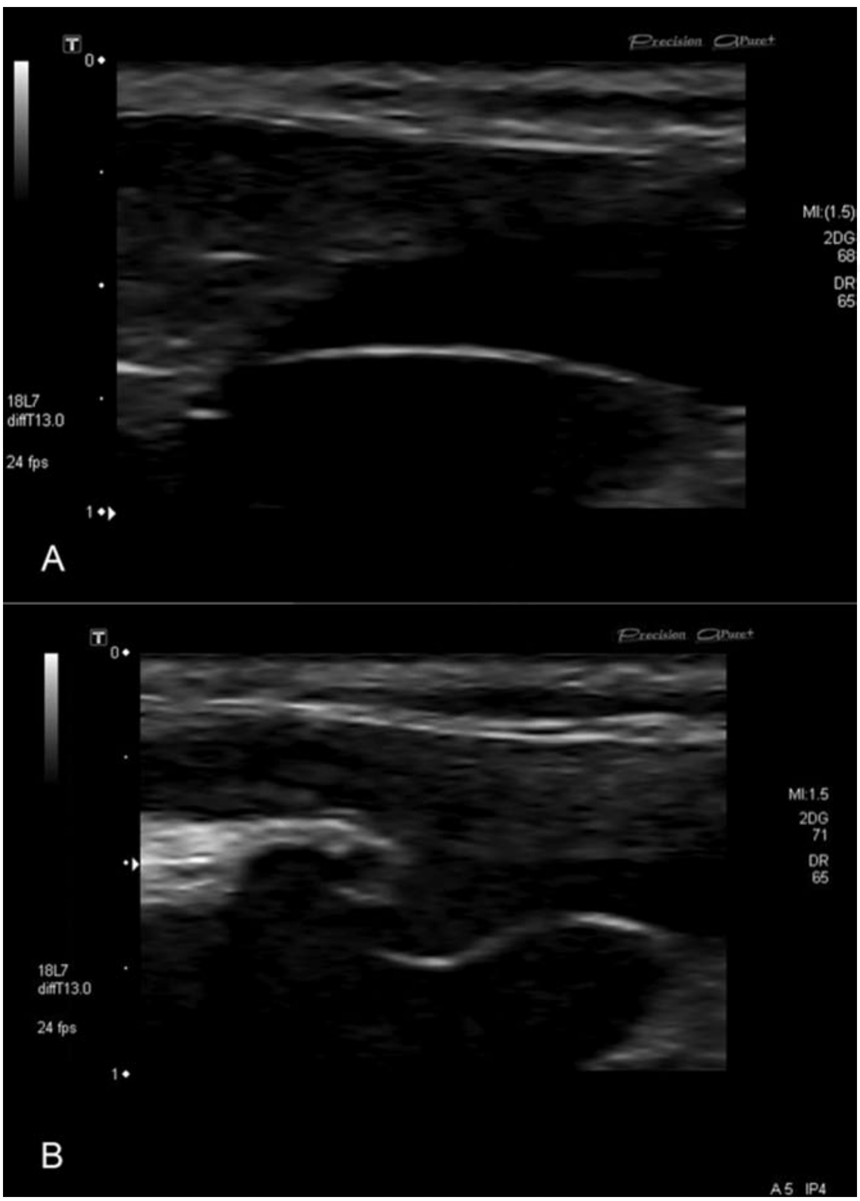

Figure 3. Images of competent monocuspid terminal valve. (A) The single terminal valve leaflet protruding across the lumen and on valsalva appearing to close against the opposite side of the vein wall. (B) Repeat B-mode ultrasound image, still without significant reflux to valsalva or distal augmentation, which revealed a previously unseen short irregular valve leaflet on the superficial wall of the great saphenous vein.

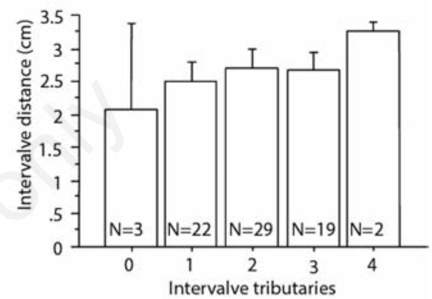

Figure 4. The relationship between intervalve distance (cm) and the number of tributary veins identified entering the intervalve segment. Error bars indicate the standard error of the mean. A higher number of tributary veins entering the intervalve segment did not associate with longer intervalve distances. Kruskal-Wallis analysis (P=0.57). Error bars indicate the standard error of the mean.

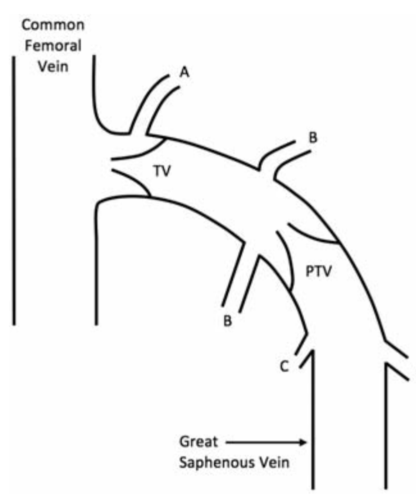

Figure 5. The structure of the great saphenous vein and its tributary veins in relation to the terminal (TV) and preterminal valves (PTV). The location of the tributaries relative to the valves may have differing haemodynamic implications corresponding to the ascending or descending etiologies of reflux development.

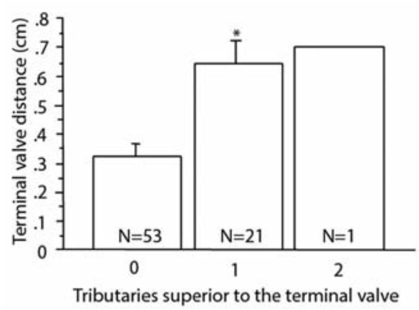

Figure 6. The relationship between the terminal valve (TV) distance (cm) from the saphenofemoral junction and the number of tributary veins identified superior to the TV *(0 vs 1 P<0.01). Shorter terminal valve distances correlated strongly with no tributaries being identified above the TV. Due to n=1 we were unable to compare the 2 tributary population against the other sub groups. Error bars indicate the standard error of the mean.

valve morphology. This difficulty may have implications in more detailed study of early mechanisms of valve dysfunction in at risk groups such as the obese subject. The suitability of this assessment for the more minimalist interventions may also be affected and perhaps intraoperative or intravenous ultrasound may give the best definition for indeterminate conventional ultrasound findings.

To minimize ambiguity, the nomenclature of terminal and preterminal valves (as defined by Caggiati *et al.*) was used.[8] The TV, the most proximal, is the first valve of the hydrostatic column of the GSV and was seen in our study in every normally functioning limb and found consistently to lie within 1.3 cm of the SFJ. This is similar to that reported by Muhlberger6 in a cadaver study at a range of 0 cm to 1.4 cm from the SFJ. It would be tempting to categorize the valves located at 0 cm in our study as ostial valves and not as terminal valves. However, Franklin states *A valve which is not inserted into the circumference of the actual entry is not an ostial, but a parietal valve, no matter how near it is to the entry.*[11] We do not believe that ultrasound, even in our idealized population, would be definitive enough to make this distinction. Interestingly, a recent report by Tasch and Brenner[12] documented a 21% incidence of ostial GSV valves, which is highly congruent with our reported 24% incidence (18/75). The definitive identification of ostial valves in the GSV may always remain dissection-based, but the long-term haemodyamic implications of having a functional bicuspid ostial valve as opposed to a terminal valve, at some distance from the orifice of the GSV, would certainly warrant further investigation.

The PTV is much more variably placed in the normal limb, as far as 8.3 cm from the SFJ. This is similar to that reported in the cadaver study in normals (1.4 cm to 8.7 cm)[6] and ultrasound imaging of patients with non varicose legs (3 cm to 5 cm).[8] The significance of this greater variability is not clear but it does give rise to considerable scope for variation to the number and identity of which tributaries enter the GSV in the segment between the TV and PTV. This may have significant implications for development of reflux and for treatment.

For example, despite the very short distance from the SFJ to the TV, 29% (22/75) of limbs had at least one tributary vessel superior to the TV (labeled tributary A in the schematic representation of the SFJ (Figure 5). The greater the distance to the TV, the more tributaries above it (Figure 6). If these tributaries were to become incompetent, reflux may be observed at the SFJ despite intact terminal and preterminal valves and no reflux in the GSV. This phenomena may apply not only to more proximal vessels draining the perineum and from above the inguinal ligament but also to the accessory GSV vessels in particular the anterior accessory saphenous vein (AASV) which Muhlberger[6] reported was often one of the most proximal tributaries identified. It is our observation that this reflux into the AASV does occur in association with clinically evident varicosities. Under such circumstances traditional ablative intervention may entail obliterating the SFJ and a non-refluxing GSV below. More minimalist intervention may simply ligate the AASV and leave the GSV intact.

The relative placement of the valves and tributaries may lead to other important variations in reflux patterns and treatments. If the descending theory applies and the TV becomes incompetent but there is an intact PTV, then reflux may similarly occur down any of the tributaries, most frequently the AASV. This pattern of incompetence was shown to occur in approximately 6% of patients presenting with varicosities.[13] If conversely the ascending theory of incompetence is in play with an incompetent PTV but an intact TV, then reflux demonstrated following valsalva is not from the CFV but from the tributaries refluxing into the GSV. The absence of one or both of these valves will have different haemodynamic implications relative to which theory of reflux development that each surgeon prescribes to.

The number of tributary veins joining the GSV was extremely variable. The classic idealized saphenous star comprised of the GSV and its five independent major superficial tributaries was not seen in this study. In some limbs, only one or two tributaries were seen. The discrepancy between our findings and the idealized saphenous star reported by Mühlberger[6] was not unexpected due to differences in methodology. The two limbs in the present study with PTVs identified at 7 cm and 8.28 cm from SFJ had the highest number of tributary vessels. Given the highly conjoined nature of the tributary vessels of the SFJ, it is probable that all 5 major tributary vessels were present in these limbs but were not identified using ultrasound. The reduced size of normal superficial veins and their associated tributary vessels, coupled with the lowered volume of flow in the normal SFJ, compounds the difficulties posed by their variable course and made ultrasound identification tributary vessels more problematic in the normal SFJ compared to in an incompetent SFJ. Mühlberger reported that in only 68% of limbs did the posterior accessory saphenous vein (PASV) drain directly into the GSV and that in many cases tributary veins merged into conjoined vessels before draining into the GSV or elsewhere. Muhlberger,[6] in their very large cadaver study reported 69 possible configurations of superficial tributary veins comprising the saphenous star. This offers a plausible explanation why five tributary vessels were not identified entering the GSV in any limbs in our study.

It appears from our study and of others that the greater the distance to the TV, the greater the number of tributary veins one should expect to find superior to the TV. A similar relationship may exist for the length of the intervalve segment and the number of tributary veins but this could not be substantiated. A larger sample size may help elucidate whether this relationship holds. These findings may have implications in surgical planning and may influence the technical success of varicose vein surgeries.

In procedures such as Endovenous Laser Therapy, closure of the GSV is limited to within 2-3 cm distal to the SFJ in order to spare the CFV from treatment effects and leaves a residual untreated proximal GSV *stump.*[14] Initially, this stump was thought to allow normal drainage of SFJ tributaries and prevent recurrence associated with these vessels as seen after venous surgery with the traditional ligation and crossectomy.[15] The variability of the distances of these tributaries from the SFJ and their variable level of conjoining with each other before entering the GSV may result in a variably draining stump. The most proximal of the tributaries would be expected to have preserved drainage but less so for the more distal, namely the PASV. Little attention has been given to the impact of therapies on the state of the valves within the residual stump. This is not surprising when it comes to SFJ high ligation and associated variations in which the whole SFJ complex is destroyed. With minimal surgery preserving the SFJ complex, the intent is to preserve the valves. The effect of endovenous therapies on these valves is less clear. The proximity of devices to the valves will vary with the location of the delicate valves.

Whether the valves remain functional may influence outcomes including stump thrombosis and patterns of recurrence. This deserves further investigation.

Limitations to the ultrasound description of normal anatomical detail include the technical issues of the depth of tissue and available imaging windows. Following tributaries is not straightforward. In cadaveric studies, it is easier to examine all these small tributaries with micro-dissection. Despite this, the number of tributaries assessed as individual vessels draining into the GSV by ultrasound was similar to the description by Muhlberger.[6] It is our impression from examining patients with reflux disease that these tributaries are larger with greater flow with venous remodeling and hence easier to identify and track. Ultimately, it is the function of these vessels rather than their identity that determines their relevance to intervention.

While it would be desirable to recommend detailed examination of the SFJ valves and tributaries for understanding of SFJ incompetence and for treatment planning purposes, it may not be possible in all patients and may not be required for traditional interventions. Eighteen subjects, out of a total of 221 subjects screened, were excluded from the current study due to unfavorable habitus. Repeated imaging was required in seven limbs when the initial examination suggested monocuspid terminal valves. Subsequently these were found to be either bicuspid (the anterior wall valve leaflet not being seen at the initial investigation) or only possessing one leaflet with degradation of the other. Further research will be required to determine the utility of the parameters examined in this study in regular practice. The increasing sensitivity of ultrasound equipment enables a more detailed examination of the SFJ and facilitates at least further research into these anatomical features and their influence on treatment outcome.

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