4 Duplex Ultrasound of Superficial Leg Veins in the Context of Saphenous Vein Sparing Surgery

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4.1 General Information on Duplex Ultrasound

The advent of duplex ultrasound revolutionised the treatment of superficial leg veins. Previous methods to investigate veins like phlebography and continuous wave Doppler (CW Doppler) have become almost obsolete. The various duplex modes have allowed a deeper comprehension of the physiology of the venous system—this has led to new techniques in the ablation strategy and completely new approaches in the treatment of varicose veins. Saphenous vein sparing surgery would not have been possible without these new insights. If Trendelenburg [1] had the possibility to perform duplex ultrasound prior to his selective interruptions of the varicose recirculation, it could be argued that the current popular methods would never have arisen.

The physics behind the generation of ultrasound, the application possibilities and the technical details of an ultrasound device are explained in many books. Furthermore, the general investigation of superficial leg veins has been extensively published [2–5].

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Details like optimising the examination environment, selection and the systematic process of performing the investigation are assumed as known. They have been covered extensively in an earlier book [5]. This chapter gives a comprehensive explanation of the many situations where it is possible to spare the saphenous vein and deliver a minimally invasive treatment to improve leg haemodynamics. It cannot be stressed enough that the knowledge of duplex ultrasound of superficial leg veins is the basis for the comprehension of CHIVA.

To be able to perform a preoperative mapping, the ultrasound machine must be fitted with a probe which detects flow in superficial and deep veins with colour and especially also with PW mode. Usually a linear probe with a frequency of 7–12 MHz is appropriate. In addition, an abdominal probe (curved array, 3–8 MHz) is required for the examination of the supra-inguinal veins and is helpful also in obese patients.

The patient will spend some time standing on an elevated platform. Elevation is important to protect the back of the investigator, as bending down to reach the leg in a person standing on the floor is uncomfortable. An additional display monitor positioned behind the leg of the patient is also helpful as this will limit neck strain. To avoid dizziness, the patient should stand on a large platform (on small areas people tend to feel they are falling). There should be the provision to hold onto a rail, with the examination table behind to give the feeling that they can sit or lie down any time.

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Confusion that seems to exist between B-mode and B-flow is common. The differences are explained below:

The plain ultrasound image without any Doppler effects is termed B-mode. It just reflects off the tissue as an image. The newer generation of ultrasound devices can detect erythrocyte aggregates moving through the veins. Slow movement and stationary regions can be seen as slightly different echogenic patterns (see Fig. 3.6). This is termed erythrocyte sludge [6, 7]. After a fast emptying of veins with a calf compression or contraction, the lumen appears black. After a few seconds, the aggregates appear again. Flushing manoeuvres aid in the identification of small veins which would otherwise be obscured by the is-dense surroundings. Colour-coded duplex can be applied to B-mode where flow is seen as red or blue, depending on the direction of flow.

The highly sensitive image of blood flow which applies Doppler and different enhancing techniques is termed B-flow. Only high-end devices are fitted with this option. It does not suffer with blooming which is the overpainting of the vessel edges with colour artefact. Further information can be found in basic ultrasound duplex books [8].

4.2 Flow Patterns in Superficial Leg Veins

The basis to recognise physiologic or pathologic flow in the superficial venous system is the flow curve in PW mode. In the standing position, only a little spontaneous flow is detectable. Different provocation manoeuvres have been described to augment the flow. They will be discussed in Sect. 4.3.

A physiological flow, as described in Chap. 3, is directed from superficial to deep and from the periphery towards to the heart. It is produced mainly by vis-a-tergo forces which include the heart, and this is augmented by muscle contraction of the venous leg pumps. This is called leg muscle pump systole. In standing position, it is often followed by a short flow in the opposite direction due to gravitational forces. This is called muscle pump diastole. Diastolic flow is impeded by valve closure in healthy veins. This is shown in Fig. 4.1 (see also Sect. 2.3.1).

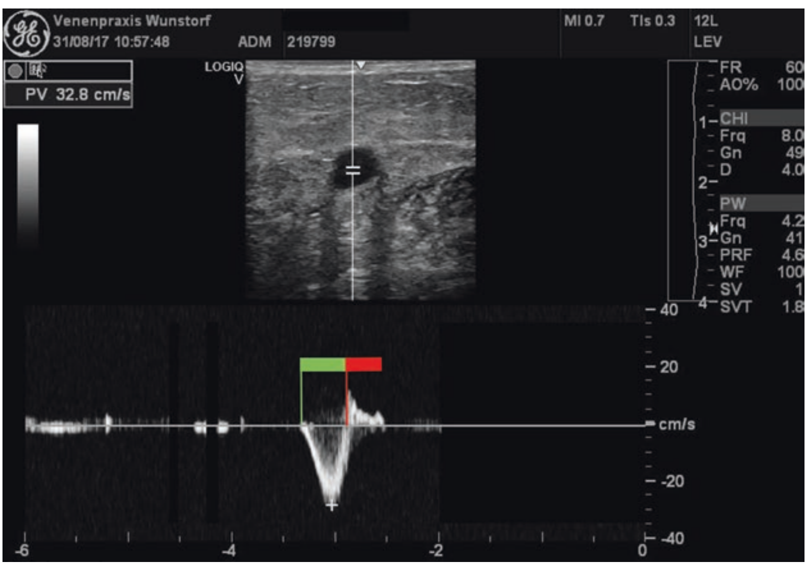

Fig. 4.1 Flow after a provocation manoeuvre in a competent leg vein. The flow in pulsed wave (PW) mode is defined as negative (below the "zero" line) when the flow is away from the probe and as positive when the flow is directed towards the probe. Antegrade physiological flow will be directed towards the heart or from superficial to deep. Here, the PW curve will be "under" zero, as shown in the image; this is the flow during muscular systole (green line), followed by a short flow in the opposite direction during the muscular diastole, caused by gravitational forces. This flow is very short, because closing valves are impeding a further flow in the false direction (red line)

If the valves do not close during diastole, in standing position there will be a retrograde flow (reflux) lasting longer than 0.5 s. Labropoulos studied healthy legs and found out that all veins with competent valves had a retrograde flow below 0.5 s [9]. This was taken as cut-off value between competent and incompetent superficial leg veins. In a recent study, it was shown that patients with reflux have mostly reflux curves lasting longer than 1 s following at least one provocation manoeuvre [10].

The PW Doppler mode measures the **velocities** of the erythrocytes per unit of time within the measurement window set by the investigator. The PW curve records these velocities as white points along the time axis. If the velocities of the individual erythrocytes are similar (laminar flow), a curve will be formed with a white contour and a black space under the curve. If different velocities are recorded (turbulent flow), the space under the curve will be filled in with white points.

Reflux may be assessed by its duration velocity. In veins these are not measured as accurately as in arteries, because of the lack of laminar flow. Besides, the vein runs parallel to the skin. This makes it difficult to achieve an angle of 45°–60° between the vein and the probe to improve the curve quality and the accuracy of the velocity measurement. Nevertheless, the shape of the curve provides useful information about the venous drainage pathways. A large vein, like a dilated saphenous vein, fed by another large vein, like the femoral vein, which then drains back into the deep veins via a large perforating vein, will have a rapid retrograde flow (see Fig. 4.2a). Long-lasting retrograde flow with slow velocity (see Fig. 4.2b) is typical in one of the following cases:

- Small blood reservoir as a source of reflux. For example, reflux from a healthy saphenous vein into a refluxing tributary.
- Small calibre link between a reflux source and refluxing vessel. For example, reflux from the pelvis through the pudendal or epigastric veins.
- Re-entry path into the deep veins that has less diameter than the refluxing segment. In this case, the drainage will be slower and more prolonged.
- Lack of compliance in the refluxing vein so that it cannot receive large blood volumes. This may occur with fibrosis after a thrombosis episode or after radiation.
- Reflux path is partially obstructed, for example, by a superficial vein thrombosis or extraluminal compression of the reflux path.

So, the shape of the reflux curve can already give us an information about some of the physiological aspects playing a role in the reflux

4.3 Provocation Manoeuvres

To examine the recirculation circuits of the superficial venous system, venous flow is an essential requirement. In the standing position, there is little spontaneous flow for assessment. Therefore, in most cases, a provocation manoeuvre is required. Competent superficial veins have little flow and will not respond well to a provocation manoeuvre. However, incompetent superficial veins will answer with a reflux in the standing position in the following situations:

- Under pressure in the abdomen, provoking reflux from above (Valsalva) (see Sect. 4.3.1)
- After having challenged the valves with an antegrade flow from below with manual compression and release of the calf or with dynamic manoeuvres like Paraná or Wunstorf (see Sect. 4.3.2)
- After the venous reservoir have been completely emptied, challenging the valves with gravitational forces like after the orthostatic manoeuvre (see Sect. 4.3.3)

Overviews about provocation manoeuvres can be found at the following links: https://www.youtube.com/watch?v=e76GcnWB7gg (German video with clear demonstration of manoeuvres)

https://phlebo.schattauer.de/inhalt/archiv/issue/1812/issue/special/manuscript/20571/show.html (download of English version)

4.3.1 Manoeuvres Using Pressure

These manoeuvres work by elevating the pressure in the thoraco-abdominal compartment, in order

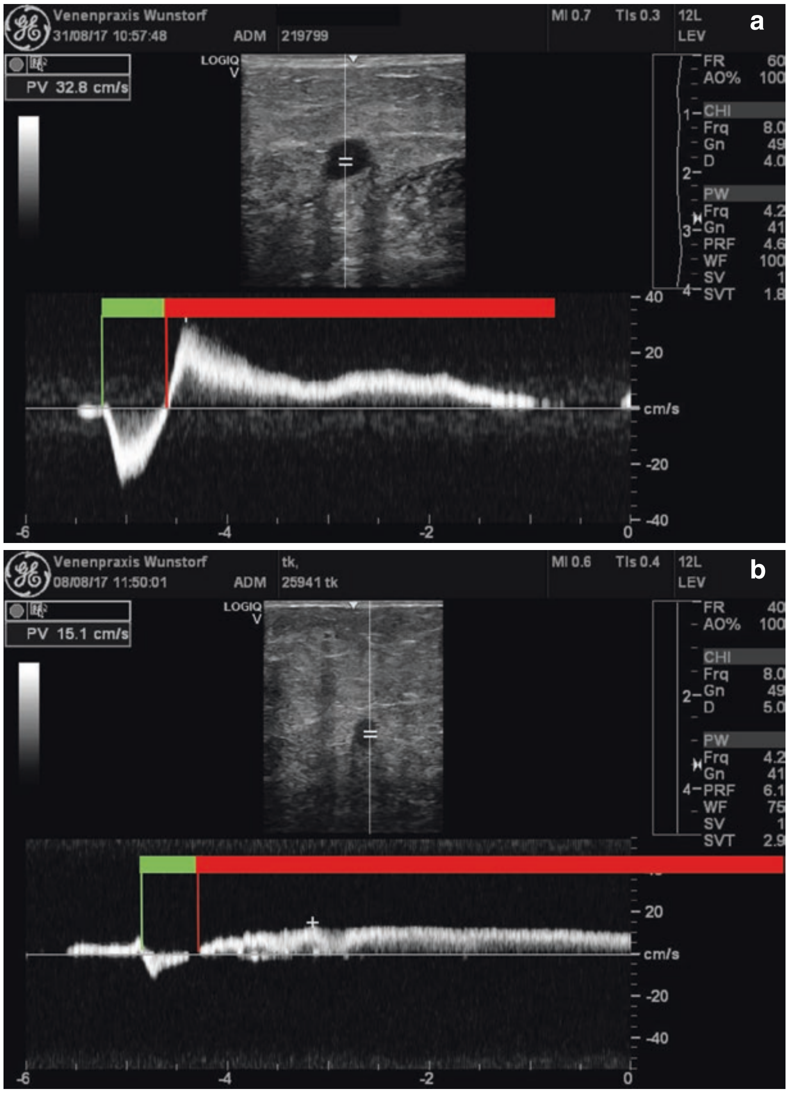

Fig. 4.2 (**a**) Well-drained refluxing vein with a high peak velocity and duration of approximately 3.5 s. Systole (green) followed by reflux (red). This image was found in a shunt type 1 with additional drainage via a tributary. (**b**) Long-lasting reflux, longer than the display of the ultrasound screen (red line). This velocity is slow which is typical for a non-drained system. This reflux was found in a pelvic shunt type 5. Typically, the antegrade flow in systole in these cases is also very slow (green)

to force venous blood back down into the legs. When the valves are competent, the flow will stop and an anterograde flow will reappear after finishing the pressure. When the valves are incompetent, the retrograde flow will be prolonged whilst the pressure is applied. These manoeuvres are independent of gravitational forces and thus can be used lying as well as standing.

These manoeuvres were the first applied in a time, when patients used to be investigated in recumbent position. Today, in standing position, the value of these manoeuvres is less—as the gravitational manoeuvres are optimal in standing position. Nevertheless, the pressure manoeuvres are especially sensitive to demonstrate pelvic reflux and should always play a role when exploring the groin.

4.3.1.1 Standard Valsalva Manoeuvre

The Valsalva manoeuvre is a blocked expiration (closed glottis) similar to defecation, delivery or weight bearing. Valsalva provokes a retrograde flow if valves are incompetent due to the transmission of a hyper-pressure gradient along the wall [11]. The reappearance of the anterograde flow when the manoeuvre stops confirms that it was properly performed. Standardised variations with devices have been developed, most of them too complicated for a daily office situation.

4.3.1.2 Cremona Manoeuvre

The Cremona manoeuvre, developed by Claude Franceschi and Roberto Delfrate, is easier to apply than the standard Valsalva manoeuvre. The patient blows air through a straw when asked. This induces a pressure increase in the thorax and abdomen, thereby forcing the venous blood back into the legs, and allows a dosage of pressure during the exploration.

4.3.2 Manoeuvres Provoking Antegrade Flow

In the standing position and with competent veins, blood flow will be antegrade, with a little backflow until the valves have closed (see Fig. 4.1). To discriminate competent from incompetent vein segments, manoeuvres need to be applied which first expel blood upwards (muscular systole) and then wait for the flow situation on muscle relaxation (muscular diastole) (see Sect. 2.3.1). Compression manoeuvres, with the hand squeezing the calf or external pneumatic cuffs, include the superficial veins and are not physiological. They should be distinguished from the physiological muscle contraction manoeuvres which involve only the venous blood within the pumping chamber [6, 7].

4.3.2.1 Manual Compression and Release of the Calf

The manual calf compression and release manoeuvre is the most common provocation test used in the evaluation of the leg veins. The calf is squeezed with one hand (systole) and then released (diastole). The manoeuvre can also be done by compressing the foot or thigh with the hand. It can be performed with standardised cuffs applying the pressure for study situations. This is not usable in daily clinical setting.

Calf compression causes antegrade flow in the superficial and deep veins. If venous incompetence is present, there will be retrograde flow when the pressure is relaxed. This manoeuvre can be performed any time without the assistance of the patient, and it always causes blood flow in open veins. The response depends on the size, force and speed of the operator's hand. It may cause pain and it provokes not a blood flow to be found in physiological conditions.

4.3.2.2 Automated Compression and Release of the Calf

Pneumatic pumps can be wrapped around the calf which can be inflated to a predetermined pressure and then deflated suddenly to induce reflux. They can be manually operated by a foot pedal leaving the examiners hands-free. Alternatively, an automated pump can be applied delivering a cycle of compression, relaxation and time for refilling to occur before the next compression cycle. The advantage of these methods is that it standardises the compression test and refilling time. Standardisation is a requirement if reflux is being quantified [12].

4.3.2.3 Paraná Manoeuvre

The Paraná manoeuvre is a physiologic manoeuvre and consists of a gentle forward push of the patient's lower back, thus provoking a calf reflex contraction to avoid falling down. This contraction causes an upstream blood flow (systole), followed by a reflux in cases of valvular incompetence [13].

4.3.2.4 Wunstorf or Toe Elevation Manoeuvre

The Wunstorf manoeuvre is a physiologic manoeuvre. It was inspired in the Paraná manoeuvre and proposed as a simple test that is easy to perform and is not demanding for the patient. Furthermore, it does not require the participation of the examiner. A big advantage of this manoeuvre is that the leg itself is not moved whilst remaining a physiological test. It is performed with the patient standing and flexing or extending the forefoot followed by a relaxation. Dorsal flexion involves hyperextension of the toes and raising them off the floor (systole) followed by a relaxation phase (diastole). Plantar flexion involves flexing the toes so that they curl under raising up the metatarsal heads and foot arch (see Fig. 4.3). These forefoot contraction and relaxation manoeuvres activate the foot muscle pump [14, 15].

In almost all patients, hyperextension of the toes causes an antegrade flow impulse,

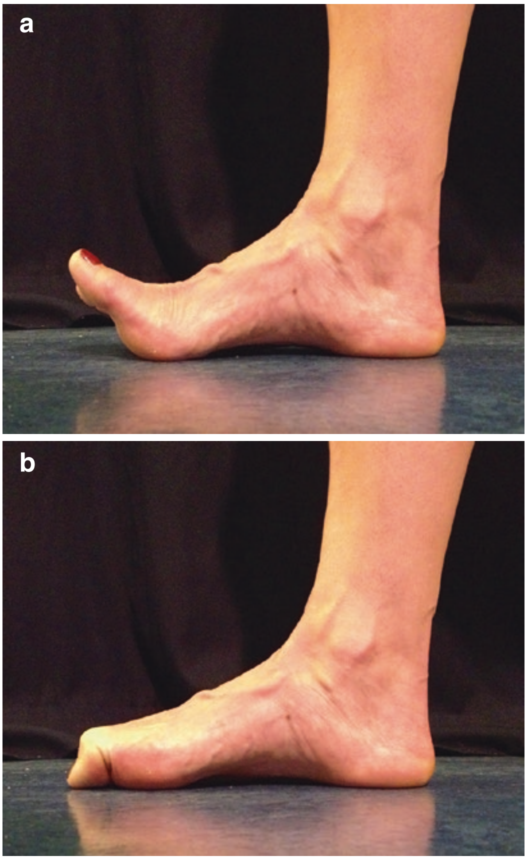

Fig. 4.3 (**a**) Wunstorf or toe elevation manoeuvre. (**b**) Alternatively, the toes can be flexed to provoke a flow in superficial leg veins. With permission by [5]

which can be measured up to the common femoral vein. Antegrade flow is generally also found in the saphenous trunk veins after the Wunstorf manoeuvre. In patients with deep or superficial vein incompetence, retrograde flow (reflux) follows the antegrade flow on relaxation.

In a recent study, these manoeuvres demonstrated to be as efficient as calf compression and release [10].

4.3.3 Manoeuvres Using Gravitation and Gravitational Volume Changes

Most manoeuvres have the inconvenience that their result depends on how the manoeuvre is performed. Inability to breathe as expected in Valsalva, small hands in compression manoeuvres and muscular contraction variations whilst maintaining stability can all influence the results. Thus, all studies which compare manoeuvres lack the security of a standardised provocation test possibly leading to interpretation errors.

4.3.3.1 Elevation-Dependency Manoeuvre

The elevation-dependency manoeuvre may close this gap: Here, the patient lies down on his or her back, with the leg to be investigated elevated straight up for half a minute. Then the patient stands up whilst the duplex ultrasound probe is simultaneously applied over the vein to be assessed. Alternatively, the emptying and filling can be performed on a tilt table.

In case of competent leg veins, no reflux will be found. In case of valve incompetence, a continuous retrograde flow is seen until venous reservoir filling. This retrograde flow will last between 20 s up to minutes, thereby giving the examiner time to look for incompetent veins [16]. The reflux ends only when the venous reservoir is full to capacity and there is no more space to accommodate further reflux [17]. This is independent of the patient or the examination factors, which leads to less bias in the results. In some patients, with visible varicose veins and lack of flow after classical provocation manoeuvres, this manoeuvre will uncover valvular incompetency that would otherwise remain undetected. This is especially true in case of non-drained systems (see Fig. 4.4).

4.4 Sapheno-femoral Junction

4.4.1 Anatomy of the Sapheno-femoral Junction

Under the groin crease, the great saphenous vein (GSV) pierces the fascia (ostium) to drain into the common femoral vein. In its last few centimetres, the GSV has two valves, the terminal valve next to the common femoral vein, at the ostial

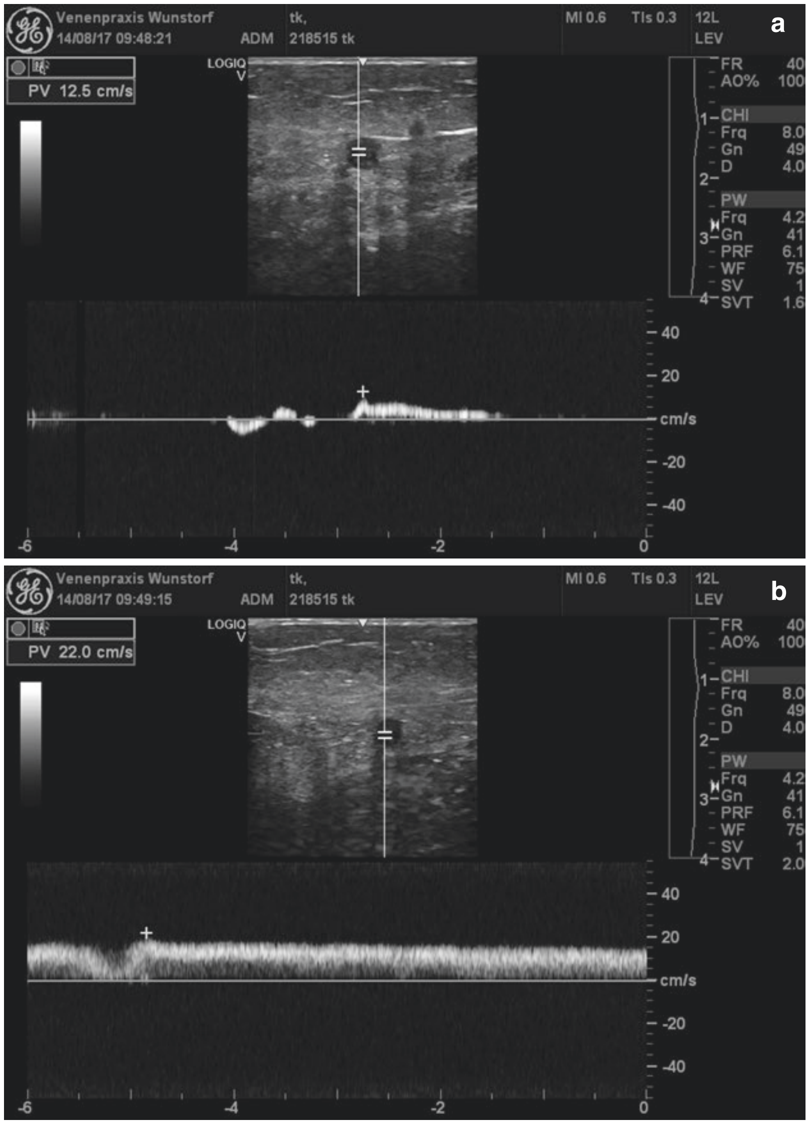

Fig. 4.4 (**a**) Little flow is observed in a patient with obvious varicose tributaries after manual compression of the vein immediately below the measuring point to improve the outcome, after finding nearly no flow with physiologic muscle contraction manoeuvres. (**b**) Flow in the same vein after lying down, lifting the leg for 30 s and then standing up again. The reflux is prolonged and lasts until the venous reservoir is full to capacity

level which is where the GSV pierces the fascia, and the preterminal valve at some centimetres further down and below the confluence of those tributaries which join in at the groin level (see Fig. 4.5).

There are many tributaries joining in the GSV at the SFJ (see Figs. 4.6 and 4.7):

- Pudendal vein from the medial side
- Posterior accessory saphenous vein (PASV), also from medial, but usually some cm further down
- Anterior accessory saphenous vein (AASV) coming from the lateral side after running on the anterior aspect of the thigh
- Epigastric and circumflex veins from lateral and coming down from the abdomen

AASV and epigastric or circumflex veins can join independently (Fig. 4.6f) or alternatively form a common vein that drains at one into the GSV (see Fig. 4.6a, b, e). These mentioned veins may be absent. And the relation between these veins and the valves is highly variable.

4.4.2 Flow in the Sapheno-femoral Junction

The sapheno-femoral junction is involved in the vast majority of patients with varicose veins. Thus, the investigation of this point of the recirculation circle is of highest importance. A recent study investigating the frequency of incidence and distribution of reflux sources in 2019 patients with venous incompetence involving the GSV at the groin is represented in Table 4.1 [19].

Of all legs, 53% had a reflux with an incompetent terminal and preterminal valve, two thirds of all patients had a reflux from the common femoral vein. Exclusive periosteal reflux was identified in 21%, and 8% had reflux from both sources

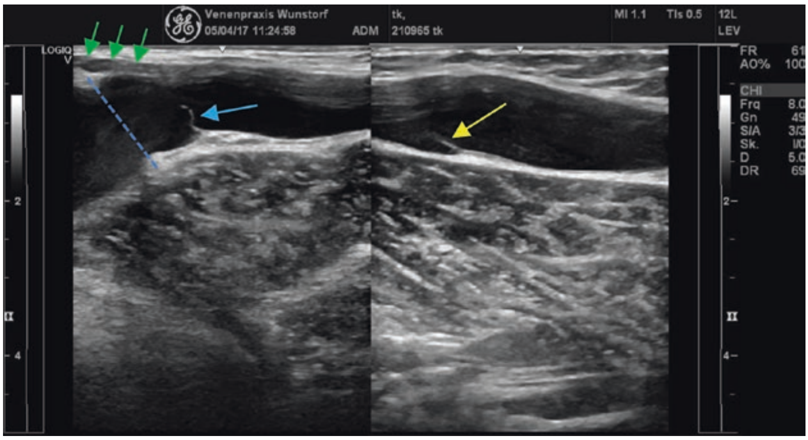

Fig. 4.5 Longitudinal view of the GSV next to the junction (composed image). At the left margin: common femoral vein, the ostium level (dotted line), the terminal valve (blue arrow) and the preterminal valve (yellow arrow) in the GSV. Joining into the GSV, we find the epigastric vein (green arrows)

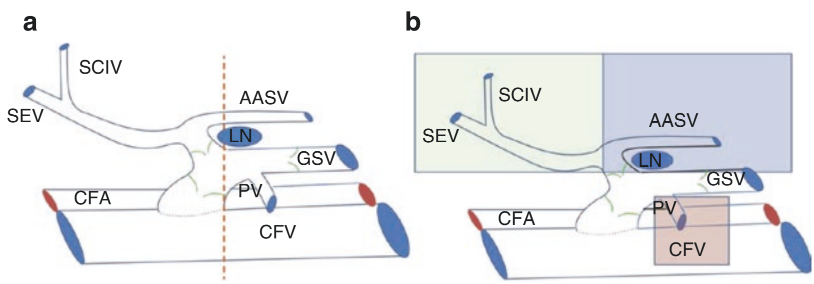

Fig. 4.6 Junctional variations and valves for common or separate inflow from the proximal and lateral tributaries. (**a**) Standard sapheno-femoral junction with tributaries. The pudendal vein is the single medial vein which joins between the terminal and preterminal valves. The lateral segment is shown with a common confluence of a cranial and caudal branch and another valve at the level of its junction with the great saphenous vein. The typical position of a lymph node (LN) lateral to the great saphenous vein is shown. The perpendicular red-dotted line marks the caudal edge of the ostium (dotted line on the CFV). (**b**) Additional information defining the lateral segment (*light green/light purple*) and the medial segment (*light brown*). The lateral segment is divided into cranial (*green*) and caudal (*light purple*) parts. (**c**) Transverse view of the lateral segment distal to the terminal valve (TV). An imaginary dotted line drawn around the front wall of the common femoral vein and passing through the confluence of the great saphenous vein will give the exact point where the great saphenous vein enters the femoral vein. This is known as the *fossa ovalis* or ostium. (**d**) Longitudinal view demonstrating the confluence of the lateral cranial segment also distal to the terminal valve. (**e**) Absent terminal valve. (**f**) All of the superficial inguinal tributaries join independently between the terminal and the preterminal valves (*CFA* common femoral artery, *LN* lymph node, *TV* terminal valve, *CIV* circumflex iliac vein, *SEV* superficial epigastric vein, *PV* pudendal vein, *AASV* anterior accessory saphenous vein, *GSV* great saphenous vein) (Drawings Dr. Andreas Hildebrandt. Berlin; by kind permission. Ultrasound images Erika Mendoza). With permission by [5]

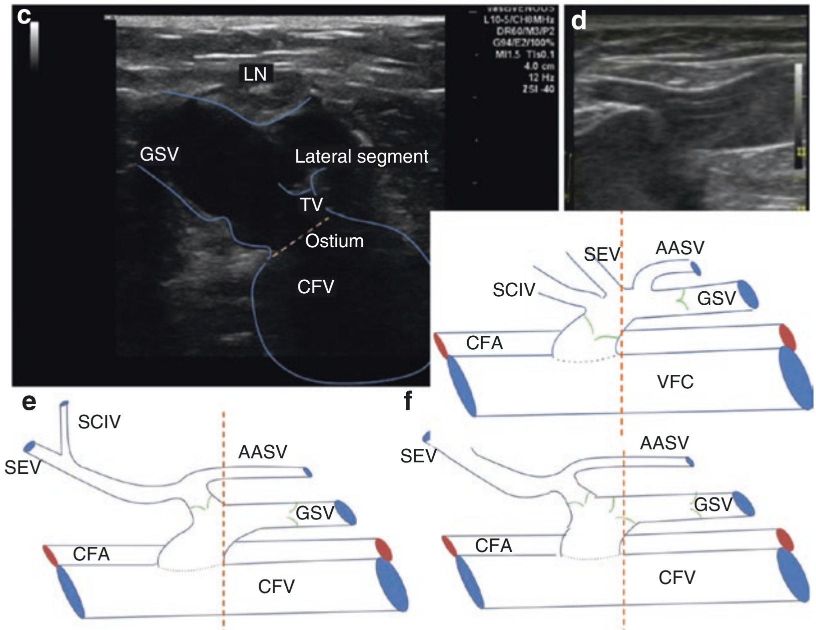

Fig. 4.6 (continued)

(periosteal and ostial). Four percent of the study population had neither a reflux from the common femoral nor the cranial tributaries (shunt type 0; see Sect. 3.7.4).

4.4.2.1 Competent Valves

When the valves are competent, there is no reflux through the valves and no backflow from the deep to the superficial vein at the SFJ. In muscular systole, the PW curve will show an inflexion "downwards" followed by a short retrograde flow (inflexion "upwards") to close the valve (curve; see Fig. 4.1).

The tributaries of the groin behave the same with a short flow towards the SFJ in diastole. Occasionally a pelvic leak point is present draining through the SFJ without provoking a reflux into the GSV. This is identified as a prolonged draining flow through the junction lasting longer than 0.5–1 s, which is fed by a refluxing pudendal, circumflex or epigastric vein. This is seen easily during a Valsalva manoeuvre: the draining flow through the junction fed by the reflux in the groin tributary will last as long as the manoeuvre. This situation is not a pathological condition for the GSV, but a drainage through the SFJ of pathologic reflux from the pelvic network. It could develop to a situation of venous insufficiency of the legs to be re-evaluated at a later stage.

4.4.2.2 Incompetent Terminal Valve and Competent Preterminal Valve

If only the terminal valve is incompetent and the preterminal is not, then there will be a reflux emerging from the deep vein through the SFJ, and it will escape into the anterior accessory saphenous vein (AASV) (see Sect. 6.5.2). This condition has been described by Stücker as Stücker type 1 (see Fig. 4.7) [20].

A schematic representation of this reflux is found in Fig. 4.7. As there is the possibility of connections between the refluxing AASV and the GSV along the leg, it is important to follow the GSV downwards the leg to make sure no calibre changes and further refluxing segments are present.

On ultrasound, the AASV is situated between the skin and the CFV in the groin, called the "alignment sign". The GSV is situated medial to the CFV (see Fig. 4.8). Therefore, a large calibre AASV

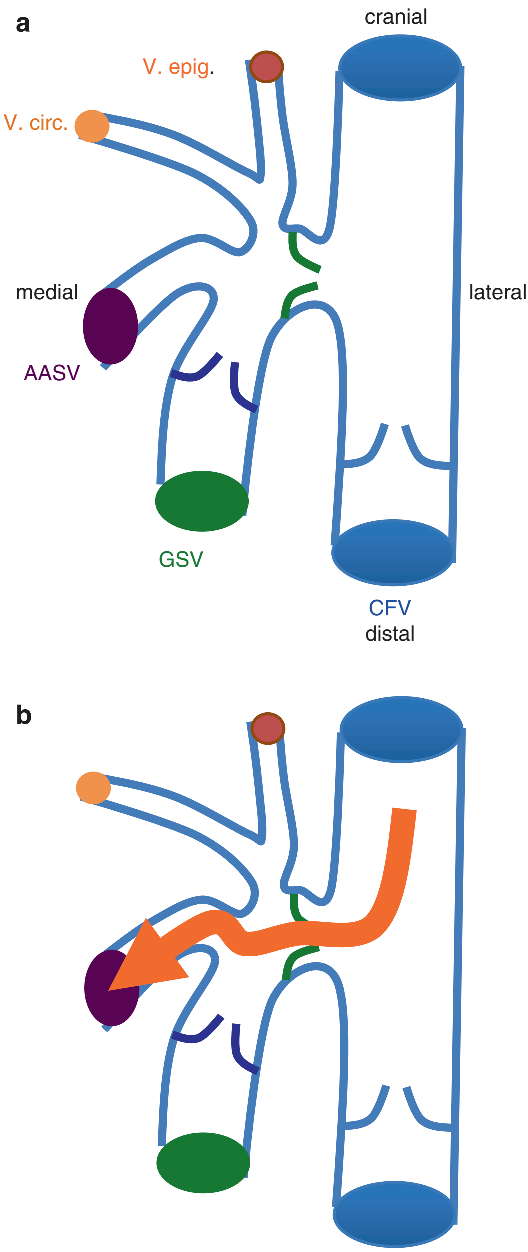

Fig. 4.7 (**a**) Schematic representation of the SFJ with terminal valve (green) and preterminal valve (violet) with legend for (**b**), Figs. 4.9 and 4.13. (**b**) Reflux path in case of incompetent terminal valve and competent preterminal valve (orange arrow) (Stücker type 1). With permission from [18]

directly over the CFV may be confused with an incompetent GSV. During systole in colour-coded duplex ultrasound, both veins are seen with antegrade blue flow (Fig. 4.8a). During diastole, the red colour represents an incompetent terminal valve with reflux escaping into the AASV (Fig. 4.8b).

4.4.2.3 Competent Terminal Valve and Incompetent Preterminal Valve

This condition is one of the most difficult to detect with ultrasound investigation (Stücker type 2, see Figs. 4.9, 4.10 and 4.11). It has also been called "para-ostial reflux", as this reflux does not emerge through the ostium. This configuration needs a confident diagnosis for saphenous sparing techniques. However, with saphenous ablation it makes no difference, whether the reflux in the GSV emerges from the deep vein or from the pelvic network. This is because in any case the reflux path will be destroyed. Recognition that the reflux source may be exclusively from a groin tributary will influence the saphenous sparing tactic and the follow-up.

The reflux might emerge from the pudendal vein (see Fig. 4.10) or the epigastric vein (see Fig. 4.11). It is important to show the competence of the terminal valve with a PW curve at this site (see Fig. 4.12) and a reflux beyond that goes into the GSV at the preterminal valve level. A Valsalva manoeuvre is essential in these cases for confirmation and to exclude a pelvic reflux source. Occasionally concurrent reflux occurs from a tributary vein as well as the junction thereby combining ostial and para-ostial reflux in one situation (see Fig. 4.11).

4.4.2.4 Incompetent Terminal and Preterminal Valve

The most frequent reflux condition in the groin is the incompetence of the terminal and pretermi-

Table 4.1 Possible combinations of reflux sources at the sapheno-femoral junction in 2.019 legs

N (%)	GSV	AASV	PASV	GSV + AASV	GSV + PASV	GSV + AASV + PASV	Sum
Type AFemoral reflux	106752.8%	1226.0%	20.1%	1547.6%	20.1%	1<0.1%	134866.8%
Type B“Both” femoral and cranial reflux	1175.8%	221.1%	0–	311.5%	0–	0–	1708.4%
Type CCranial reflux	31415.6%	743.7%	20.1%	391.9%	1<0.1%	0–	43021.3%
Type 0	633.1%	30.1%	0–	50.2%	0–	0–	713.5%
Sum	156177.3%	22110.9%	40.2%	22911.3%	30.1%	1<0.1%	2019100%

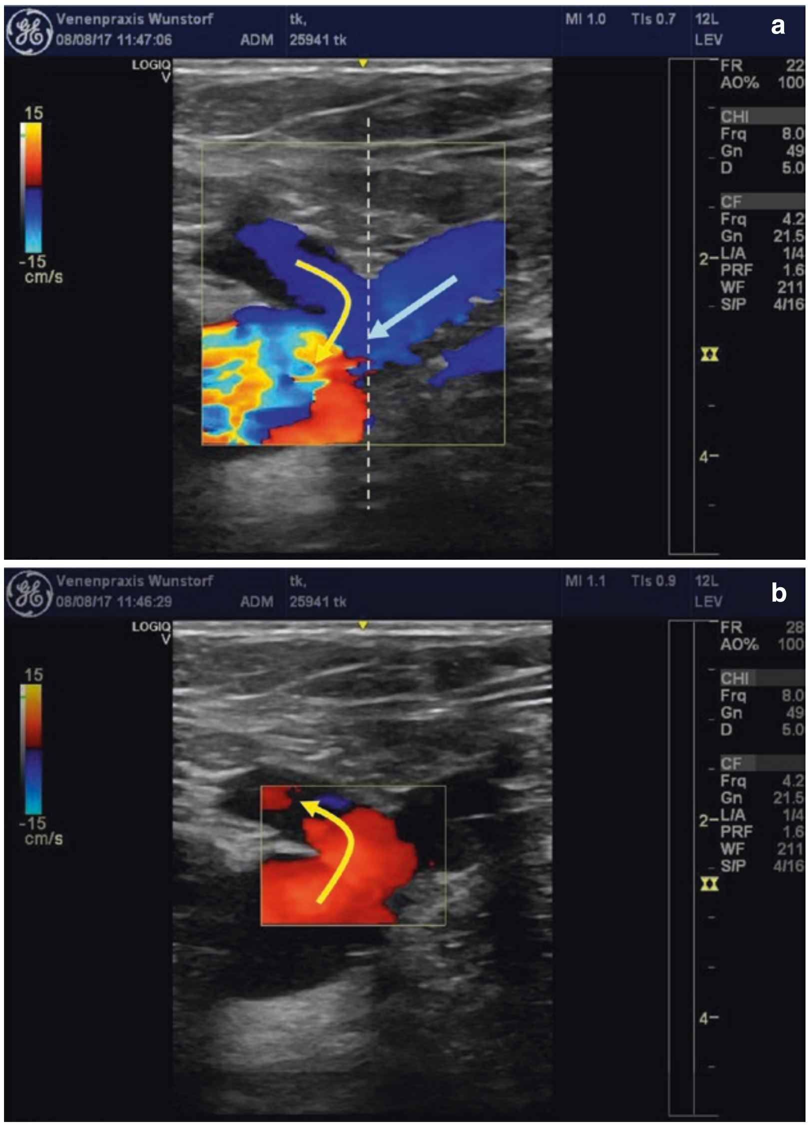

Fig. 4.8 (**a**) Cross-section through the groin during muscular systole. Both the AASV (yellow arrow) and the GSV (blue arrow) represent blue flow in colour-coded duplex ultrasound. This is because the flow is away from the probe and towards the deep vein. In the deep vein the flow has to change direction, provoking turbulences. This is represented with blue, yellow and red flow signals. The dotted line at the medial margin of the CFV explains the “alignment sign”: Medial to this line the GSV is found, lateral, between the CFV and the skin, the AASV. (**b**) Muscular diastole with reflux from the CFV through the incompetent terminal valve into the AASV (yellow arrow). The GSV does not receive any reflux

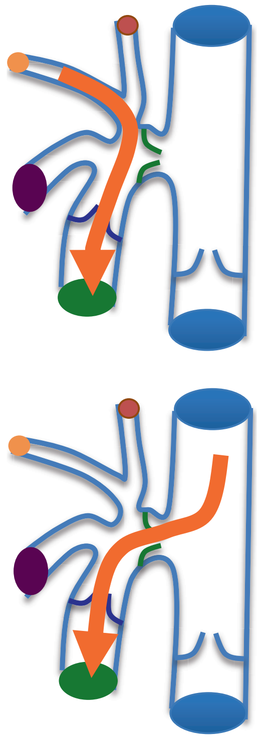

Fig. 4.9 Schematic representation of a para-ostial reflux (Stücker type 2) with an incompetent terminal valve and competent preterminal valve. Reflux into the GSV is via an incompetent circumflex vein. Note that the reflux could also emerge from the epigastric or pudendal vein. With permission from [18]

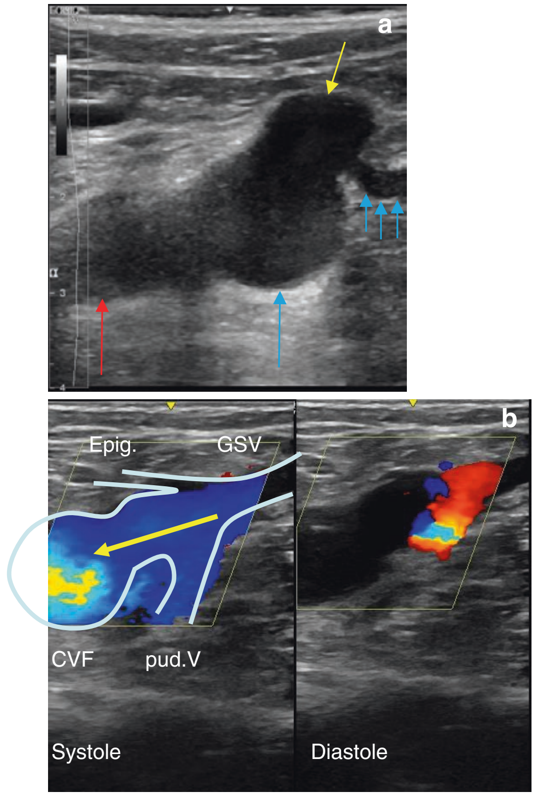

Fig. 4.10 (**a**) Cross-section through the right groin demonstrating the common femoral artery (left, red arrow), the common femoral vein (middle, single blue arrow), the SFJ and the GSV (yellow arrow). The pudendal vein (blue arrows) is shown draining into the GSV. (**b**) Flow in colour-coded duplex ultrasound with a diagonal representation of the SFJ (another patient than **a**). The anatomic structure is painted as "overlay" to the left image. A pudendal and an epigastric vein is present. Left image in systole: antegrade flow draining into the CFV (yellow arrow) and filling the last centimetre of the pudendal vein, which is not the physiologic situation. Right image in diastole: reflux from the pudendal vein into the GSV (pudendal vein with red flow). There is no reflux from the deep vein into the GSV

nal valve. Here the reflux arises from the femoral vein through the junction into the GSV and down the thigh (Stücker type 3; see Fig. 4.13). It is important to demonstrate using ultrasound the origin of the reflux in the femoral vein and passing through the terminal valve (see Fig. 4.14).

4.4.2.5 Summary: Reflux Sources at the Sapheno-femoral Junction

At the sapheno-femoral junction (SFJ), there are many different reflux source possibilities, alone or in combination (see Table 4.2). It is important in the context of saphenous vein sparing surgery to differentiate these diverse reflux situations properly prior to deciding the strategy.

Summarising the different reflux sources or finding out which of these is the one present in each patient, a flow chart can be applied (see Fig. 4.15) or a table (see Table 4.2).

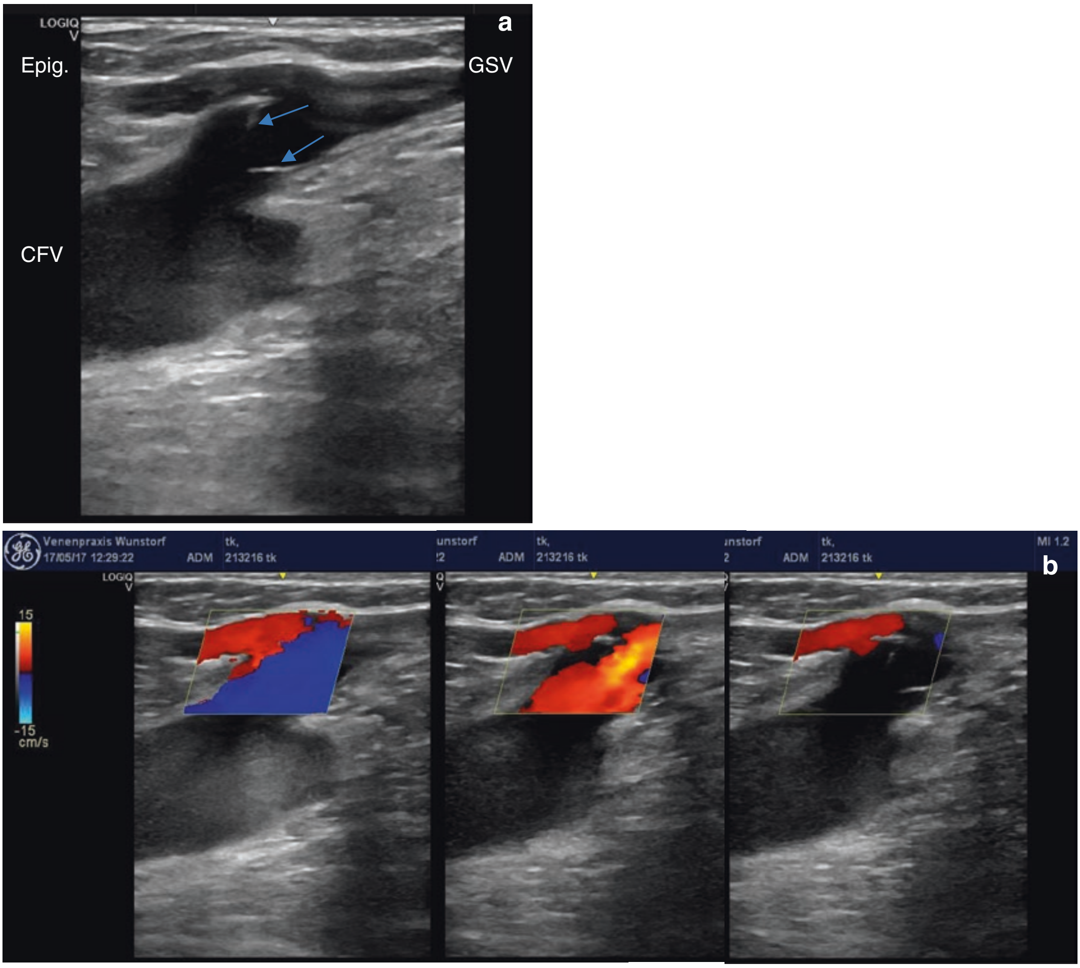

Fig. 4.11 (**a**) Longitudinal section through the common femoral vein (CFV) and the sapheno-femoral junction with visible terminal valves (blue arrows). (**b**) Same patient in colour duplex examination: left, systole with antegrade flow (blue) from the GSV through the SFJ into the CFV. The epigastric vein drains into the GSV (red flow). Middle: early diastole with reflux from the deep vein and the epigastric vein into the GSV. Right: later diastole; the reflux through the terminal valve is finished; only a long-lasting reflux through the epigastric vein feeds the GSV. This is a case of combined Stücker types 2 and 3. If only the reflux situation depicted on the right image was present, it would be an isolated epigastric reflux or para-ostial reflux, Stücker type 2

4.5 Great Saphenous Vein

The vein involved in the majority of situations with superficial vein insufficiency is the great saphenous vein (GSV). It is also the vein mostly taken as a graft for femoral or cardiac bypass interventions.

4.5.1 Anatomy

The GSV runs from the inner part of the foot anteriorly to the medial malleolus up to the groin, as shown in Fig. 4.16. As described in Sect. 2.2.3, it is wrapped between the muscle and the saphe-

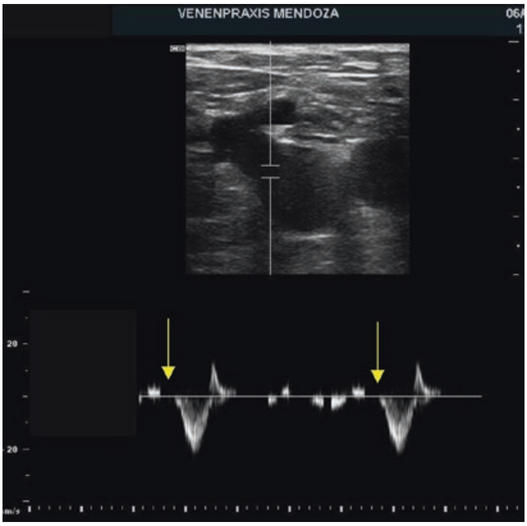

Fig. 4.12 Examination of the competence of the terminal valve using PW: the competence or incompetence of the terminal valve is assessed with PW inside the femoral vein at the ostium level; the competence or incompetence of the terminal valve is identified. This can be performed in cross-section as shown or in longitudinal section (see Fig. 4.14d). Yellow arrows: antegrade flow in systole. Short backflow in diastole until the terminal valve closes. No reflux is present

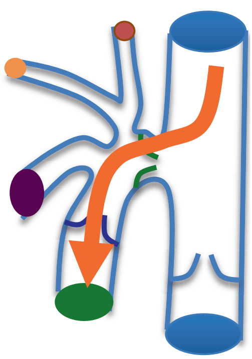

Fig. 4.13 Schematic representation of Stücker type 3: incompetent terminal and preterminal valve. Reflux from the common femoral vein trespasses the incompetent terminal and preterminal valve and fills the GSV. With permission from [18]

nous fasciae. Sometimes its course is aplastic or hypoplastic, with continuing superficial tributaries acting as a bypass for these segments. There are three typical possibilities (depicted in Figs. 4.17, 4.18 and 4.19: type I, Fig. 4.17; type h, Fig. 4.18; type s, Fig. 4.19). Very seldom a double GSV is found in the fascial compartment (1%). The GSV has to be examined in B-mode from the groin to the ankle to see calibre variations, mayor tributaries, perforating veins and aplastic segments. These are all relevant for the treatment plan. Diameters at the junction and 15 cm below should be measured in cross-section, as they will help in decision-making. It is easier to follow the GSV in cross-section, though sometimes a longitudinal scan will show more details. The GSV is easy to find at the mid-thigh by positioning the probe in cross-section. The GSV runs between the fasciae with the typical image of the Egyptian eye (see Fig. 4.17).

4.5.2 Flow and Reflux in the Saphenous Vein and Tributaries

In combination with the B-mode examination, the flow in the examined segments will be measured. Although this is easier to do in colour-coded duplex, the documentation should be performed in PW modus. If these measurements are taken in cross-section, the probe will have to be positioned slightly angulated, allowing an angle between the flow and the probe. In perpendicular position over the skin, no flow may be detected with misleading results. The top of the probe should always be angulated upwards (see Fig. 4.20).

Also in PW mode, possible supplemental reflux sources can be assessed. At the end of the

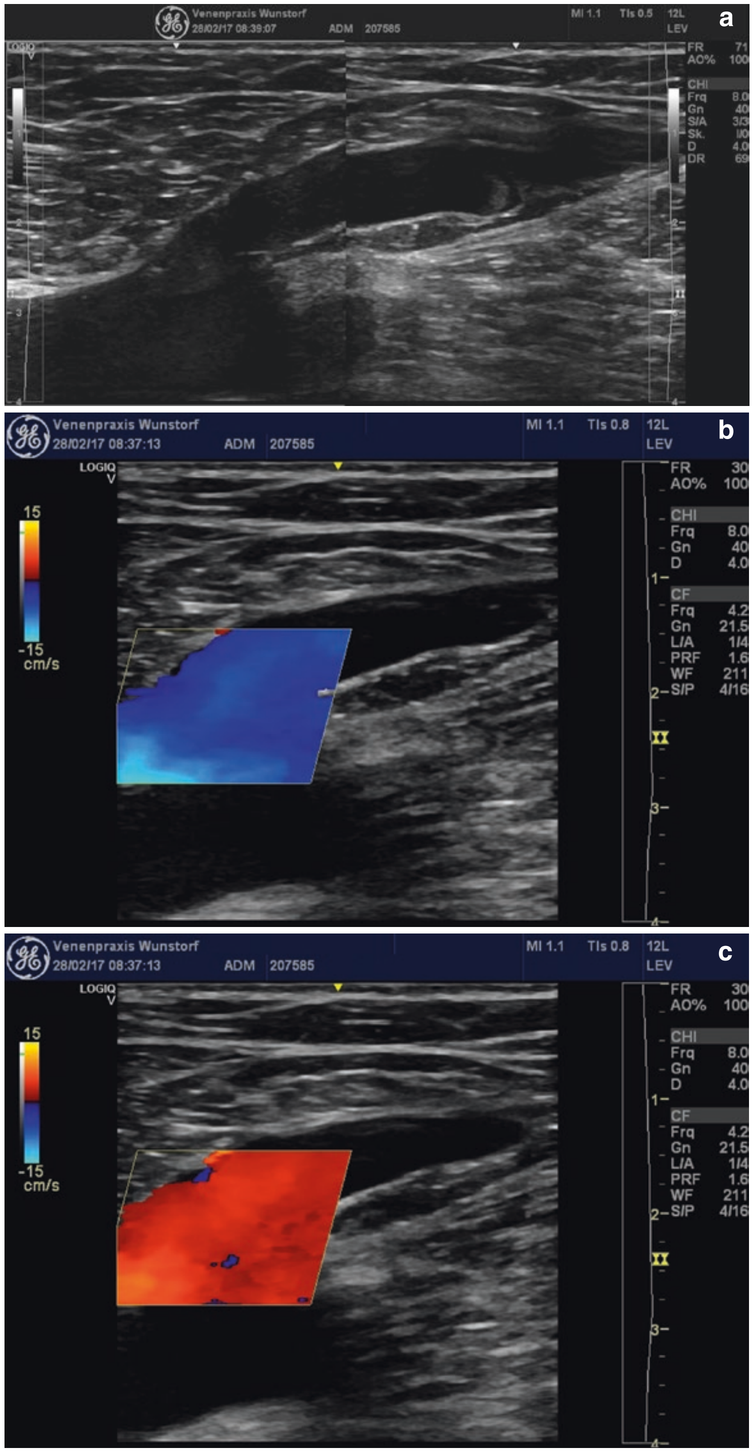

Fig. 4.14 (**a**) Longitudinal representation of the sapheno-femoral junction with terminal and preterminal valve. (**b**) Muscular systole in colour-coded duplex with antegrade flow from GSV into CFV. (**c**) Muscular diastole with retrograde flow from CFV into the GSV through an incompetent terminal valve. (**d**) Measurement in PW mode in longitudinal section at the level of the terminal valve with reflux. (**e**) Measurement in PW mode at the level of the preterminal valve with reflux. (**f**) Measurement in PW mode at the ostium in cross-section demonstrating reflux—compare with Fig. 4.12

Fig. 4.14 (continued)

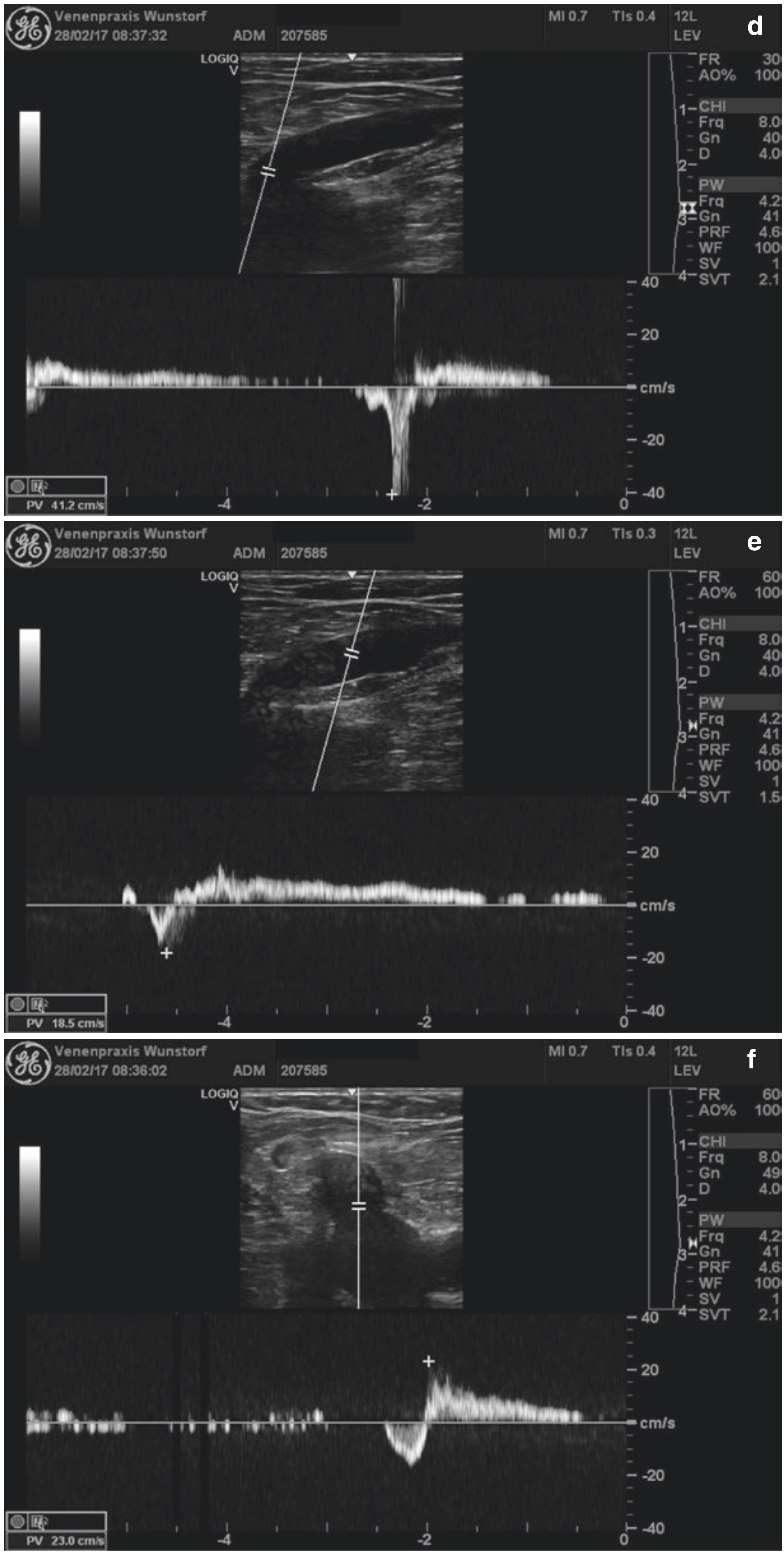

Table 4.2 Paths for different flow patterns in the groin region, including the Stücker type and the shunt type (explanation: see Sect. 3.8)

Path	Description	Clinics	Stücker type	Shunt type
CFV–TV–GSV–AASV	Incompetent terminal valve. Competent preterminal valve. GSV is only affected for a short distance. "Ostial reflux"	Visible tributaries on the anterior thigh	1	3
CFV–TV–GSV–PTV	Ostial reflux, GSV reflux above and below knee	Tributaries along the medial aspect of thigh and calf	3	1 or 3
PV–GSV–PTV	Para-ostial reflux feeding the GSV, competent TV	Tributaries along the anterior thigh and calf	2	4 or 5
PV–AASV	Reflux from pelvic venous network directly into AASV, without involving the GSV or flowing "through" it between the TV and PTV but without incompetence of any of both	Tributaries on the anterior thigh	4[a]	6
GSV (sufficient)–AASV	Antegrade flow in GSV feeding the AASV	Small tributaries at the ventral aspect of the thigh	–	2
SSV–PASV–GSV	GSV filled via a Giacomini anastomosis (origin SSV). The TV is competent and in most cases the PTV also	Tributaries at the medial aspect of the calf, possibly veins at the dorsal thigh	–	Combined 3 (SSV) and 4 or 5 (GSV)
PV–PASV–GSV	GSV filled from pelvic reflux via PASV. The TV is competent and in most cases the PTV also	Tributaries at the medial aspect of the calf or distal thigh, possibly veins at the dorsal thigh	–	4 or 5

CFV common femoral vein, *TV* terminal valve, *PTV* preterminal valve, *GSV* great saphenous vein, *SSV* small saphenous vein, *AASV* anterior accessory saphenous vein, *PASV* posterior accessory saphenous vein, *PV* pelvic veins
[a]Lit: Mendoza and Stücker [21]

examination of a refluxing GSV, the following points need answers:

- The source of the reflux.
- A possible second source, like a perforating vein.
- Is there only one segment refluxing or is there multisegmental reflux in the GSV?
- The length of the refluxing segment.
- The drainage path of the reflux load into a perforating vein or a tributary.

4.5.2.1 Reflux Source

The most frequent reflux source for the GSV is the groin region (see Sect. 4.4). Other options are:

- Refluxing tributaries, possibly fed by:
  – Pelvic vein reflux
  – Refluxing small saphenous vein via the Giacomini vein at the thigh
  – Refluxing small saphenous vein via communicating vein at the calf
  – Tributaries fed by perforating veins and draining into the GSV
  – Healthy tributaries draining into the GSV
- Perforating veins feeding the GSV directly at the mid-thigh or from paratibial perforating veins below the knee

After examining the sapheno-femoral junction, the probe will be held transversally, and the GSV will be followed down the thigh, passing

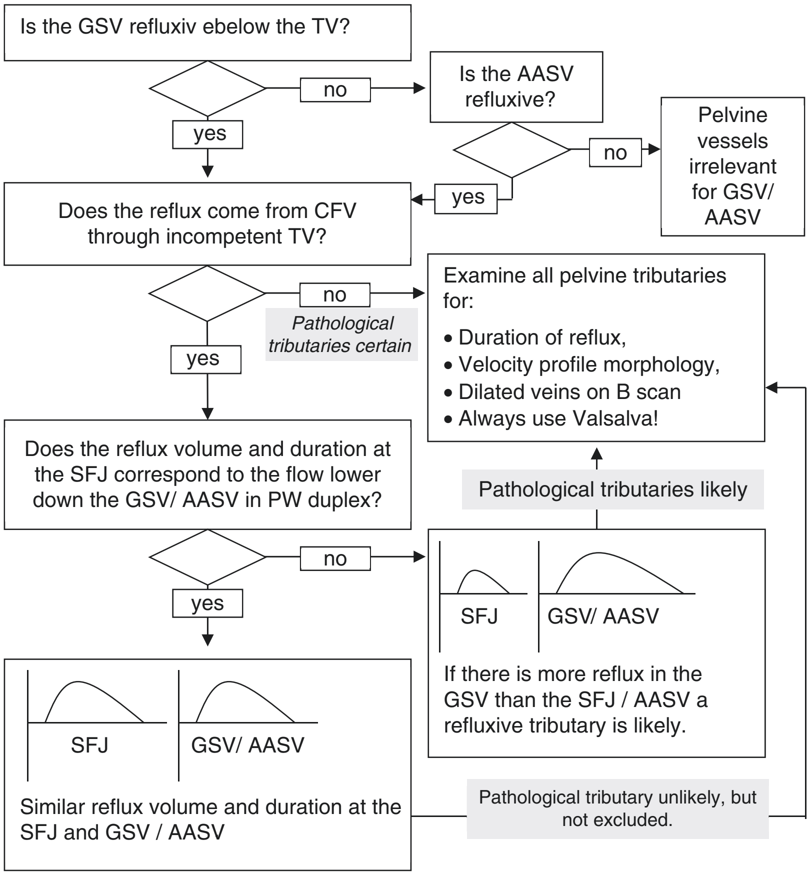

Fig. 4.15 Flow chart to determine the possibility of reflux in pelvic or inguinal tributaries as reflux source for great saphenous vein (GSV) or accessory anterior saphenous vein (AASV). Abbreviations (see legend Table 4.2). Adapted from [5]

Fig. 4.16 Course of the great saphenous vein along the right leg. With permission by [5]

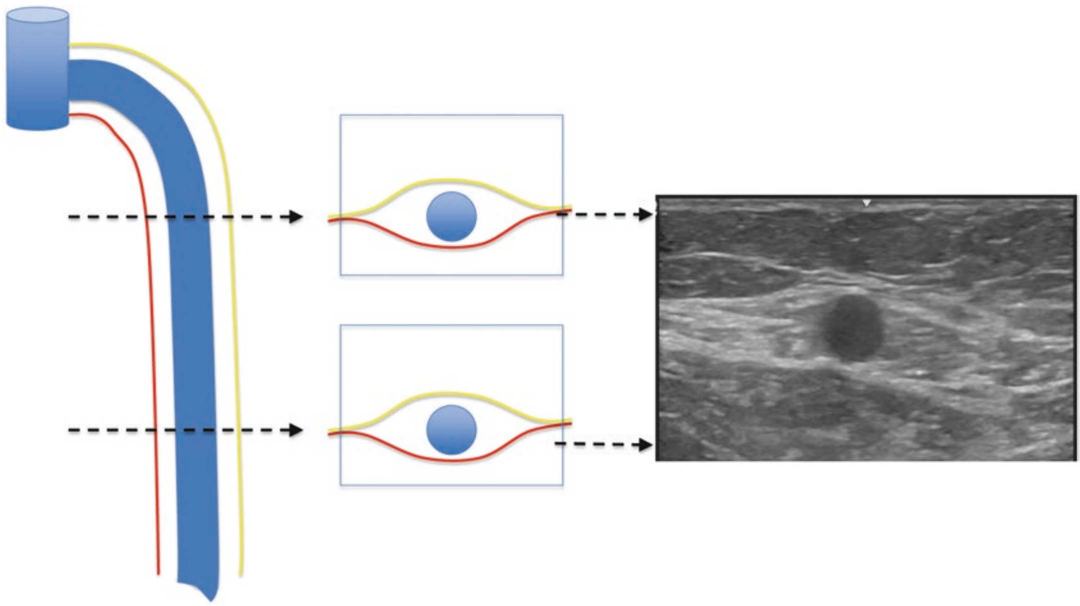

Fig. 4.17 Course of the GSV type "I". The vein has a straight course within the saphenous fascia which is confirmed at both ultrasound points in the thigh; on the right side is a typical image, visible on ultrasound at both points (Course of GSV at the thigh and knee. Schematic representation of a typical ultrasound image in B-mode in cross-section. Red, muscle fascia; yellow, saphenous fascia; blue, saphenous vein). With permission by [5]

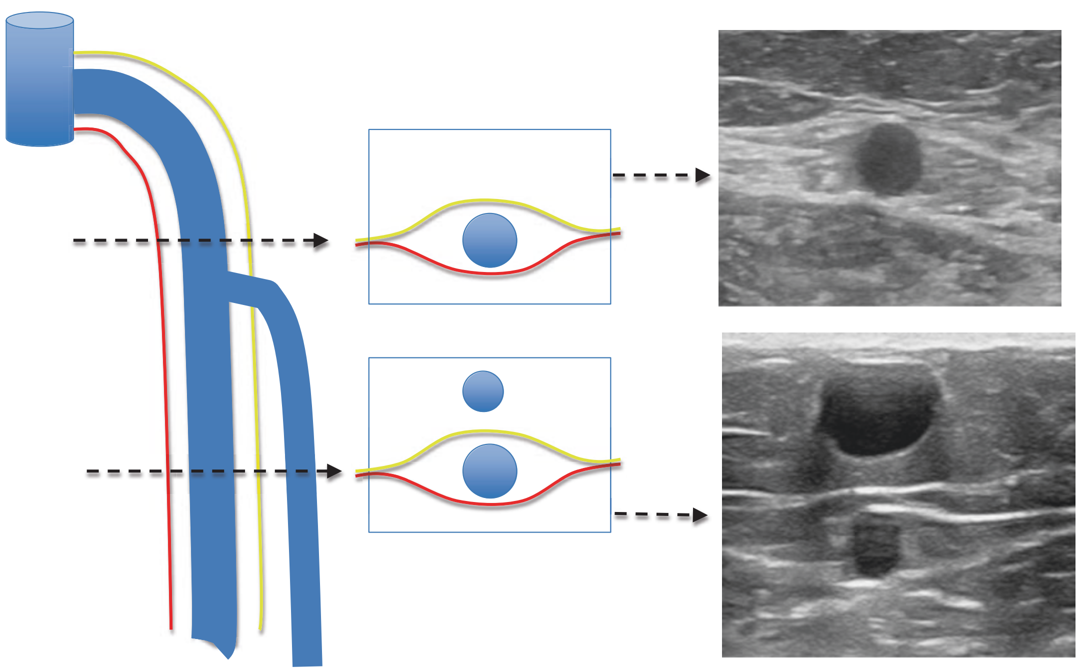

Fig. 4.18 Course of GSV type "h". The GSV has a straight course within the saphenous fascia. There is a parallel extrafascial tributary, joining the GSV at the mid-thigh. At the proximal point, the saphenous vein is seen in the compartment, and at the distal ultrasound point, there are two veins, one in the compartment and the other in the extrafascial tributary (Course of GSV at the thigh and knee. Schematic representation of a typical ultrasound image in B-mode in cross-section. Red, muscle fascia; yellow, saphenous fascia; blue, saphenous vein). With permission by [5]

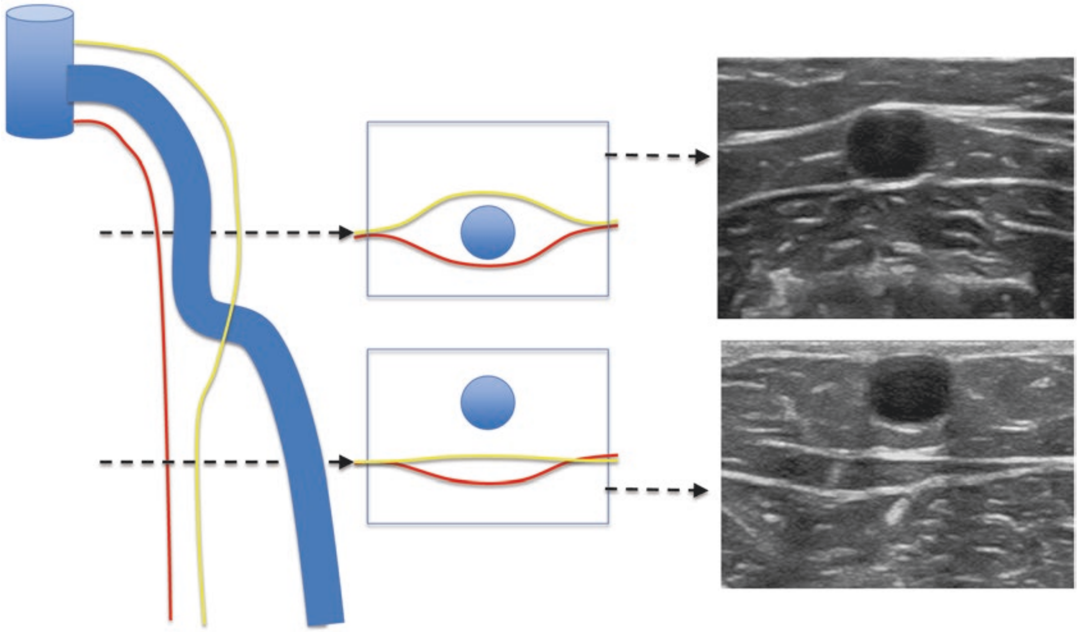

Fig. 4.19 Course of GSV type “s”. The vein runs in the fascial compartment at the proximal point and leaves the fascia so that at the distal point there is no vein seen inside the fascial compartment. However, an aplastic or hypoplastic rudiment is present on histology, but not visible by ultrasound. The main continuing tributary takes over the blood flow of the GSV as a superficial natural bypass (Course of GSV at the thigh and knee. Schematic representation of a typical ultrasound image in B-mode in cross-section. Red, muscle fascia; yellow, saphenous fascia; blue, saphenous vein). With permission by [5]

Fig. 4.20 Probe position to measure a flow in the superficial leg veins when exploring with the probe in transversal position. The tip of the probe is angulated upwards

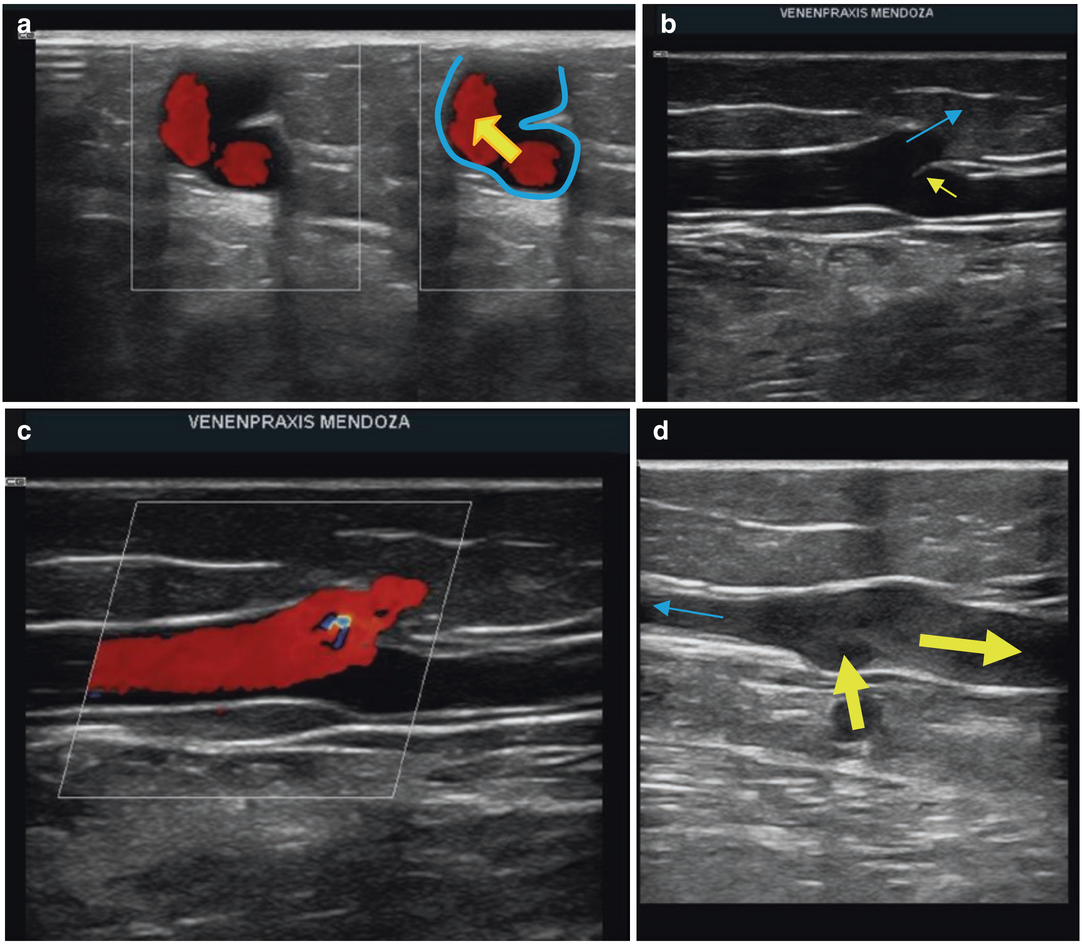

Fig. 4.21 Calibre changes in the GSV. (**a**) Cross-section at the medial thigh in colour-coded duplex during diastole: a tributary is refluxing and the reflux emerges from the saphenous vein to feed the tributary. On the right side, the shape of the GSV and the emerging tributary is depicted in blue; the direction of the flow from the GSV to the tributary is shown with a yellow arrow. During systole (not shown), the flow in the tributary and the GSV is antegrade, "blue" (Image with kind permission of Viavital from: Mendoza E. Duplexsonographie der oberflächlichen Beinvenen in Rabe E. Stücker M Phlebologischer Bildatlas. Viavital. 2015). (**b**) Longitudinal representation of the GSV at the mid-thigh in B-mode. Proximal (left part of the image) the GSV is larger; after a tributary joins the GSV (blue arrow), the distal GSV is smaller. A valve can be seen in the GSV (yellow arrow). Distally to the valve, the GSV is competent. (**c**) Same patient than in (**b**) in muscular diastole in colour-coded duplex. The reflux from the proximal GSV fills the tributary. (**d**) Longitudinal representation in another patient. Proximal GSV is competent (blue arrow). At the mid-thigh, a calibre change is seen, where a refluxing perforating vein feeds the distal GSV with reflux (yellow arrows)

the knee and then down to the ankle. Any variation of the calibre of the vein and any branching vein—perforating vein or tributary—with more than approximately 2 mm diameter must be analysed with duplex in PW mode (see Fig. 4.21). Keep in mind, that there are possibly more than one reflux sources or drainage pathways present. Awareness to this possibility will lead to less error and encourage to a better, more informative, examination.

Sometimes a reflux in the GSV is found with apparently no reflux source. This situation is called "reflux without source" and is based on the physiological feeding of the GSV by tributaries.

Here the valves in the GSV are not competent, and this physiological blood volume is drained retrogradely and demonstrated as reflux in the GSV (see Fig. 4.22).

4.5.2.2 Refluxive Segments

The most common configuration is that the GSV has one segment of reflux, fed by the SFJ and is drained via one or more tributaries or one or more perforating veins or both. Occasionally, GSV reflux feeds a tributary, the distal GSV is competent for a segment and further down will be fed again by the same tributary or another reflux source. After the exploration, it has to be clear, which segment or segments of the GSV is refluxing (Fig. 4.23).

4.5.2.3 Drainage Pathways

Identification of the drainage pathways is crucial if saphenous vein sparing surgery is performed. In the GSV the drainage of the reflux is only possible via one or more perforating veins or tributaries or both. They will be found exploring the complete GSV and analysing the flow behaviour inside the vein above and below any visible tributary or perforating vein. The reflux elimination test is useful to determine whether a segment is drained by a tributary (described in Sect. 3.8.9).

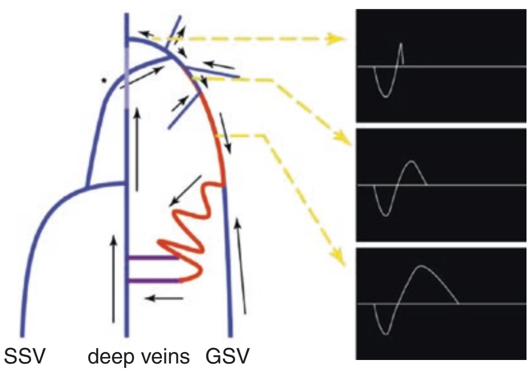

Fig. 4.22 Reflux without source according to Cappelli and Franceschi. The terminal valve of the great saphenous vein (*GSV*) remains competent. Antegrade blood from healthy tributaries, including the posterior (*) and anterior accessory saphenous veins, drain progressively into the great saphenous vein, causing retrograde flow within an incompetent segment of the GSV. There is no pathological connection with the deep system. The reflux curves are of small volume but progressively increase down the great saphenous vein. These are shown on the right at three different stages. *SSV* small saphenous vein. With permission by [5]

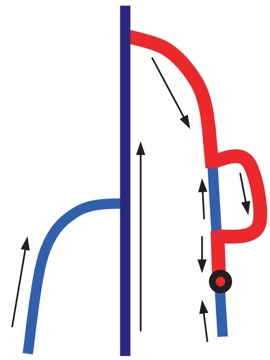

Fig. 4.23 GSV with two refluxing segments: One from the groin to the distal thigh, where the reflux drains into a tributary, which further down again joins the GSV and fills it with reflux. This second, distal segment drains into a paratibial perforating vein. The segment of GSV at the knee level is competent, as it is being bypassed by the refluxing tributary. The segment of the GSV between the ankle and the draining perforating vein is also competent, because the reflux path is diverted away by the re-entry perforating vein. With permission by [22]

4.6 Small Saphenous Vein

The small saphenous vein is the shorter, interfascial vein in the leg, running at the back of the calf (see Fig. 4.24). It is less commonly affected by a reflux.

4.6.1 Anatomy

The SSV runs from the lateral malleolus at the back of the calf, usually ending at the knee level. In 60% of cases, it has a thigh extension, which often meets the posterior accessory saphenous vein forming the Giacomini anastomosis, which connects both saphenous veins at the thigh (see Figs. 4.24 and 4.25c, f). Unlike the GSV, which always drains into the deep vein at the saphenofemoral junction below the groin crease, the drainage of the small saphenous vein is variable (see Fig. 4.25). Rarely, it drains into muscle veins below the knee or via a communicating vein into the GSV, also below the knee. In these cases, the SSV will be absent in the popliteal fossa (see Fig. 4.25g). Usually, the SSV drains into the popliteal vein in the popliteal fossa or into the first segment of the femoral vein, where it may pierce or not a muscle at the back of the lower thigh (see

Fig. 4.24 Posterior view of the leg demonstrating the course of the small saphenous vein (SSV) as a green line and the course of its thigh extension or Giacomini anastomosis as a red line. With permission by [5]

Fig. 4.25a, d, e). In addition, it may give a connecting vein into a muscle vein before draining into the deep vein (see Fig. 4.25b).

Prior to any treatment decision, it is crucial to identify, which of the described conditions are present and which of these paths have reflux (see Sect. 6.7).

The SSV runs between two fasciae, like the GSV. It is possible to confuse the SSV with a muscle vein, especially when the muscle vein has reflux (see Fig. 4.31).

4.6.2 Flow and Reflux in the Small Saphenous Vein

The small saphenous vein has to be examined from the popliteal fossa to the ankle in cross-section with close attention to flow, calibre changes, joining tributaries and perforating veins. As in the GSV, the SSV can have one or more reflux sources and one or more refluxing segments (see Sect. 4.5.2).

Many different reflux sources may feed the SSV with reflux:

- Popliteal vein via sapheno-popliteal junction (see Figs. 4.26, 4.27, 4.28 and 4.29)
- Muscle vein connecting to the SSV (see Fig. 4.30)
- Refluxing Giacomini vein, fed by the GSV (see Sect. 6.11.6.1), a posterior thigh perforating vein or by pelvic reflux
- Refluxing tributaries, fed by the GSV or occasionally a perforating vein
- Refluxing perforating vein (see Fig. 4.31)

Reflux in the SSV may be systolic, diastolic or both. A systolic reflux at the sapheno-popliteal junction is a sign of an antegrade thigh drainage obstruction to the venous flow of the deep veins (see Sect. 3.9.3). In these cases, the SSV is often only affected for a very short segment, between the deep vein and the origin of the Giacomini vein.

4.7 Perforating Veins

Perforating veins usually drain blood from superficial veins to the deep venous system during diastole. This flow is with the orientation of the venous valves which face inwards. Only dilated perforating veins or perforating veins involved as reflux source or drainage pathway for a varicose vein have to be investigated with flow measurement.

4.7.1 Anatomy

There are lots of perforating veins in the leg. Some of them concentrate along the GSV, others along the SSV and some independent veins can be also important for venous pathology. This includes the perforating vein on the back or lateral part of the mid-thigh (“Hach” perforating vein), often feeding an isolated refluxing tributary.

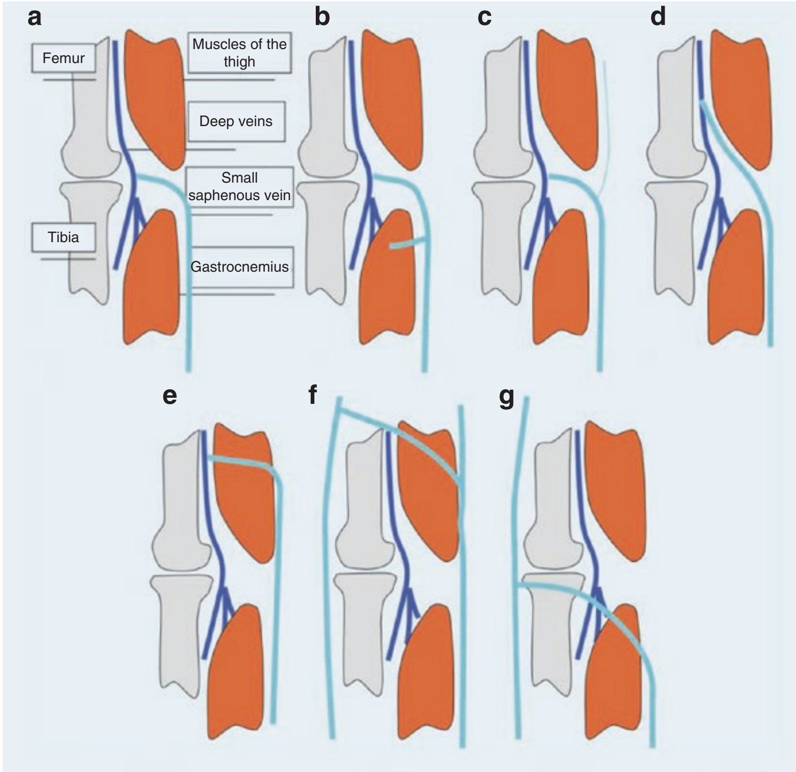

Fig. 4.25 Variations of the termination of the small saphenous vein: (**a**) Termination of the small saphenous vein (SSV) in the popliteal fossa draining into the popliteal vein (see Fig. 4.26). (**b**) Termination of the SSV in the popliteal fossa with an additional connection to the deep vein through the muscle veins (see Fig. 4.30). Sometimes the SSV only drains via a muscle vein and not directly into the popliteal vein (see Fig. 4.27). (**c**) Termination of the SSV in the popliteal fossa. The SSV has a "thigh extension" running cranially to drain via a perforating vein or meet the posterior accessory saphenous vein with an additional connection to the GSV. This intersaphenous connection is called Giacomini anastomosis (Fig. 4.26). (**d**) Termination of the SSV above the popliteal fossa without piercing the muscle fascia (Fig. 4.28). (**e**) Termination of the SSV above the popliteal fossa where it pierces the muscle fascia and the muscles of the back of the thigh. (**f**) No junction at the knee level. Termination of the SSV draining into the vein of Giacomini or femoropopliteal vein with drainage into the great saphenous vein or the gluteal veins (see Fig. 4.29). (**g**) Termination of the SSV via a connecting branch vein into the great saphenous vein below the knee. The true terminal segment of the SSV is absent, and there is no sapheno-popliteal junction present in the popliteal fossa. With permission by [22]

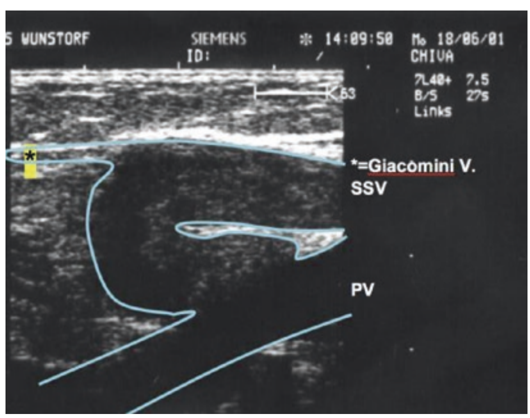

Fig. 4.26 Longitudinal scan through the popliteal fossa showing a very enlarged and refluxing SSV draining into the popliteal vein (PV). A small Giacomini vein (*) drains into the SSV (treatment: see Fig. 6.22c). With permission by [5]

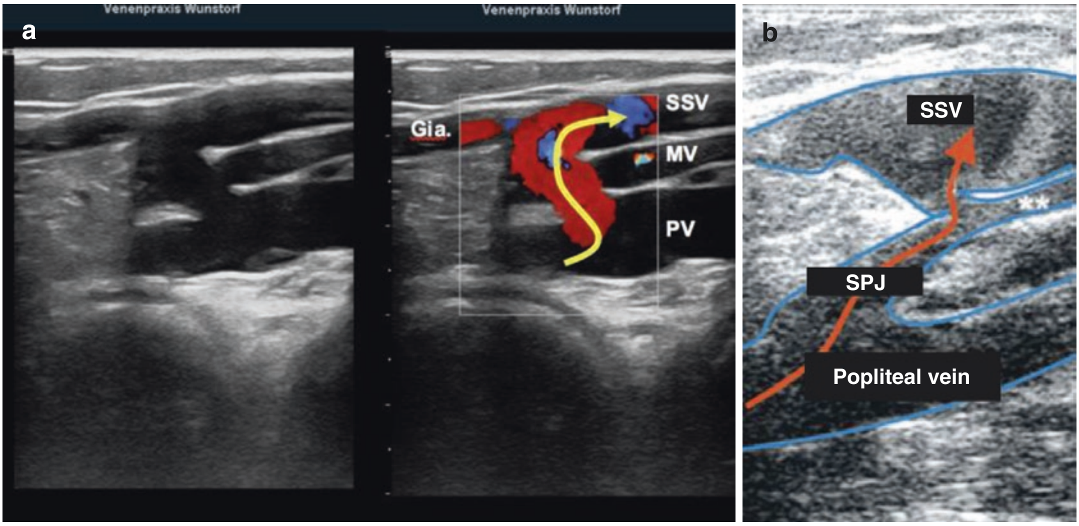

Fig. 4.27 (a) Longitudinal scan through the popliteal fossa showing the drainage of the SSV into a muscle vein. Both together drain into the popliteal vein. Reflux from the popliteal vein into the SSV is shown during the muscular diastole in colour-coded duplex ultrasound. (**b**) Longitudinal scan through the popliteal fossa demonstrating a venous aneurysm at the termination of the small saphenous vein (*SSV*). This joins the popliteal vein together with a competent muscle vein (**). The aneurysm has partially thrombosed. The arrow indicates the direction of flow of the refluxing blood. *SPJ* sapheno-popliteal junction (treatment: see Fig. 6.22b). With permission by [5]

Fig. 4.28 Longitudinal image of the popliteal fossa with a SSV draining into the deep vein below the thigh posterior muscle, above the knee crease

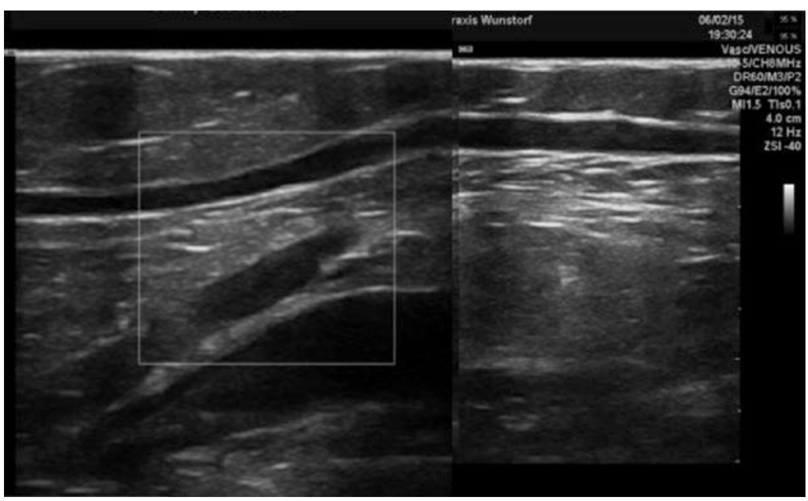

Fig. 4.29 Longitudinal composite image of the popliteal fossa with a SSV passing through the fossa without connection to the deep vein. Usually in this configuration, there is no reflux in the SSV

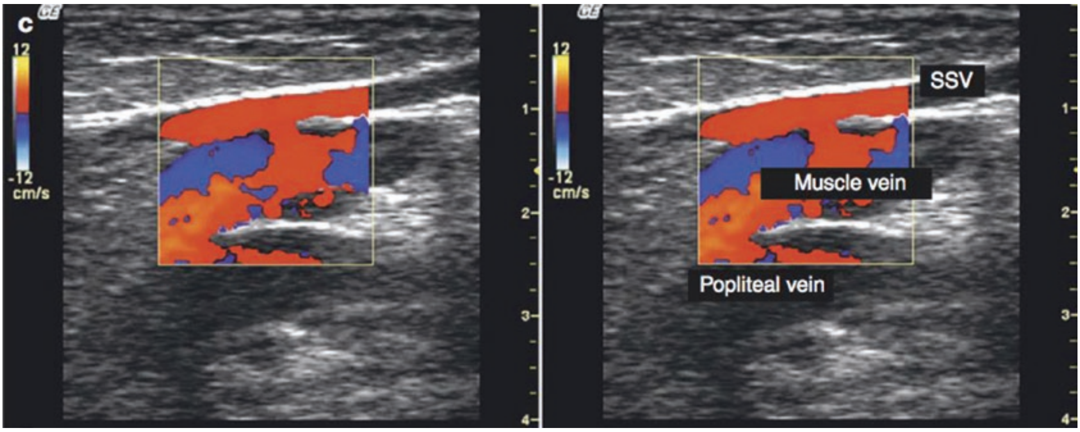

Fig. 4.30 Longitudinal view through the lower part of the popliteal fossa. The small saphenous vein (*SSV*) has reflux at the junction (not shown). In addition, there is reflux via a muscle vein. There is often a connection with the muscle veins in this region. If only the junction of the small saphenous vein is interrupted because this distal connection was not discovered in preoperative scan, then distal SSV reflux may persist. With permission by [5]

Figure 4.32 shows the most important perforating veins as a schematic representation. Perforating veins have been renamed in an international consensus. However, many people still use the former names. In these figures both names will be mentioned.

4.7.2 Flow in Perforating Veins

Dilated perforating veins have been thought to be pathologic in the sense of them being "responsible for varicose veins" for a long time. It was the ultrasound that identified the truth. Most of the perforating veins are dilated, because they drain the blood from the varicose veins back into the deep veins (see Sect. 2.4.2 and Fig. 4.35). Only those perforating veins with outward flow in systole and/or diastole are pathological (see Table 3.2 and Sect. 3.5.3 and Figs. 4.33 and 4.34).

Usually those perforating veins, which exhibit reflux in diastole, are the reflux source of a varicose vein. They are mostly found at the thigh and very seldom at the calf (see Fig. 4.33). A perforating vein can also be the second reflux source along an incompetent vein. Occasionally an incompetent saphenous vein can be fed through the sapheno-femoral junction and fed again by reflux via a perforating vein of the medial thigh. Rarely a refluxing perforating vein is identified in systole. If they are seen, they are usually part of an open bypassing shunt after deep vein thrombosis (see Fig. 4.34 and Sect. 3.7.3).

Draining perforating veins will have flow in diastole from superficial to deep and can be found at the end of the refluxing segment of a vein (terminalising perforating vein) or on the way of a refluxing segment (non-terminalising perforating vein) (Fig. 4.35).

4.8 Tributaries

Tributaries are veins running in the subcutaneous tissue superficial to the saphenous fascia. The most important tributaries are:

- Tributaries from the GSV (see Fig. 4.35)
  - Anterior accessory saphenous vein (AASV)
  - Posterior accessory saphenous vein (PASV)
  - Accessory vein at the calf (anterior and posterior)

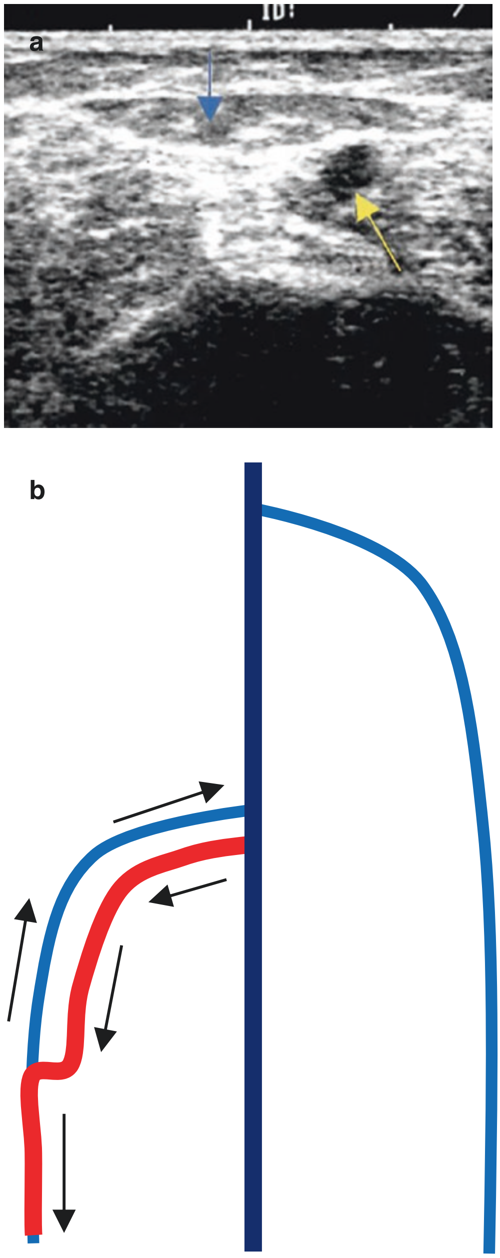

Fig. 4.31 (**a**) Transverse view through the back of the calf showing a competent small saphenous vein (*blue arrow*) and a refluxing muscle vein (*yellow arrow*). (**b**) Diagram of the recirculation circuit with incompetence of a muscle vein (red) arising from the popliteal fossa. This fills the lower part of the small saphenous vein which is also refluxing the proximal part of the SSV remains competent (blue). (**a**) With permission by [5]. (**b**) With permission by [22]

  – Communicating vein between AASV and GSV
  – Communicating vein between GSV and SSV at the calf
  – Giacomini vein
- Tributaries from the SSV (usually at the knee crease or mid-calf)

These tributaries are present, but are not always visible. If pathological they are dilated and much more likely to be visible clinically and when examining the GSV or SSV with ultrasound.

Every dilated vein connecting with a saphenous vein has to be examined with duplex ultrasound.

- Blue flow will be present:
  – If they drain into the GSV with normal physiologic blood flow less than 1 s in diastole
  – If they fill the GSV with reflux excessive blood flow lasting longer than 1 s in diastole, like in case of reflux from pelvic venous network draining into the GSV or multisegmental reflux in GSV
- Red flow will be present if the tributary is filled with reflux from the saphenous vein being dilated by the volume overload (Fig. 4.21)

The special flow behaviour of the AASV and PASV has been explained in Sect. 4.4.

Apart from the veins connected to the saphenous vein, every visible dilated and meandering superficial vein has to be examined making sure the source and the termination point of the reflux. The reflux source can be a perforating vein, the pelvic network, a saphenous vein or another tributary that branches into several other tributaries. Drainage pathways usually are perforating veins, but saphenous veins can also serve as a draining pathway for tributaries.

To detect if there are one or several draining or branching points along a very meandering tributary, the technique explained in Fig. 4.36 can be

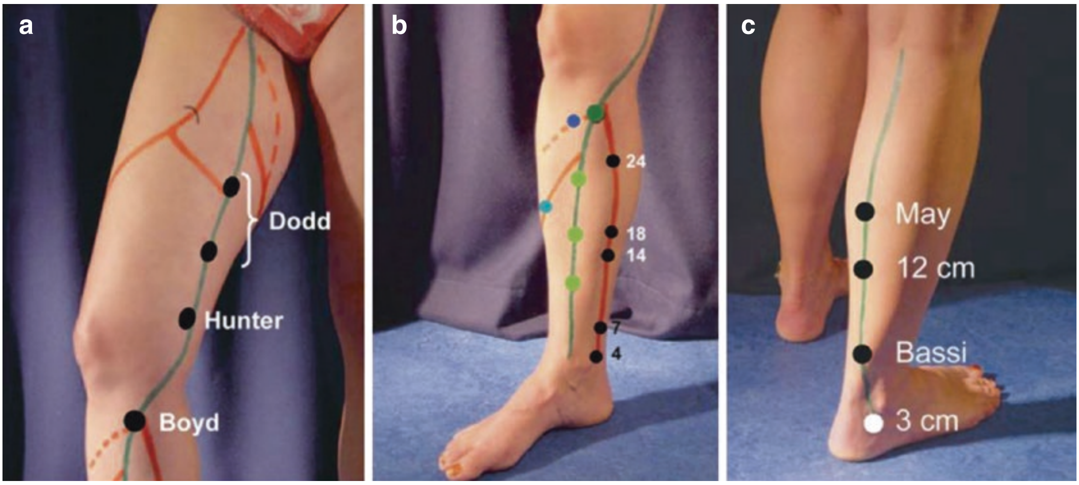

Fig. 4.32 (**a**) Location of the perforating veins of the adductor canal (formerly Dodd and Hunter) in the above knee great saphenous vein and location of the highest and most important paratibial perforating vein (formerly Boyd) in the below knee great saphenous vein. (**b**) Location of the perforating veins on the front and inner sides of the calf. *Blue*, perforating veins of the anterior arch vein; *green*, paratibial perforating veins of the great saphenous vein; *dark green*, formerly Boyd perforating vein; *light green*, paratibial perforating veins with drainage into the posterior tibial veins; *black*, posterior tibial perforating veins. These are perforating veins draining the posterior arch vein, formerly known as Cockett I–III, depending on the distance in cm between the floor and the vein. The posterior ankle perforating veins were formerly known as Kuster veins, starting at 4 cm. (**c**) Location of the perforating veins of the SSV from proximal to distal: The soleal perforating vein (formerly May) connects the SSV with the muscle veins in the middle of the calf at the so-called gastrocnemius point, a perforating vein at a height of 12 cm, a para-Achillean perforating veins (formerly Bassi). Both these connect the small saphenous vein with the fibular veins. Below the lateral malleolus, there is a direct connection between the small saphenous vein and the fibular (peroneal) veins at a height of 3 cm (lateral ankle perforating vein). With permission by [5]

applied: First, the probe is placed at the upper end of the vein to be examined. Next, the subject is told to raise and lower his toes (Wunstorf manoeuvre). In this way reflux can be confirmed in this vein segment. Then the segment below the varicose vein is compressed with one finger, and the subject is again asked to activate the muscle pump. If there is no drainage point between the probe and the point of digital compression, there will be no reflux in the first phase of muscular diastole. However, after the digital compression is released (top two curves in Fig. 4.36), reflux will resume. If a refluxing tributary branches off between the middle and lowest compression point, the waveform changes. With digital compression at the lowest point of the varicose vein in the figure, the reflux begins at the onset of muscular diastole which is independent of digital compression. This is because the refluxing volume is now drained by another tributary (bottom curve).

4.9 Deep Veins

Blood flow in the deep veins should be directed to the heart, just like in the superficial veins during systole with a short retrograde flow until the valves close. This should be no longer than 1 second to define competency of valves. The normal vein wall is represented as a thin line without thickenings or bulges.

The pathology and exploration of the deep leg veins are explained in Chap. 8. Nevertheless, during the exploration of the superficial veins, deep veins at the groin (common femoral vein) and the knee (popliteal vein) are automatically in the focus of the probe. In the groin, the com-

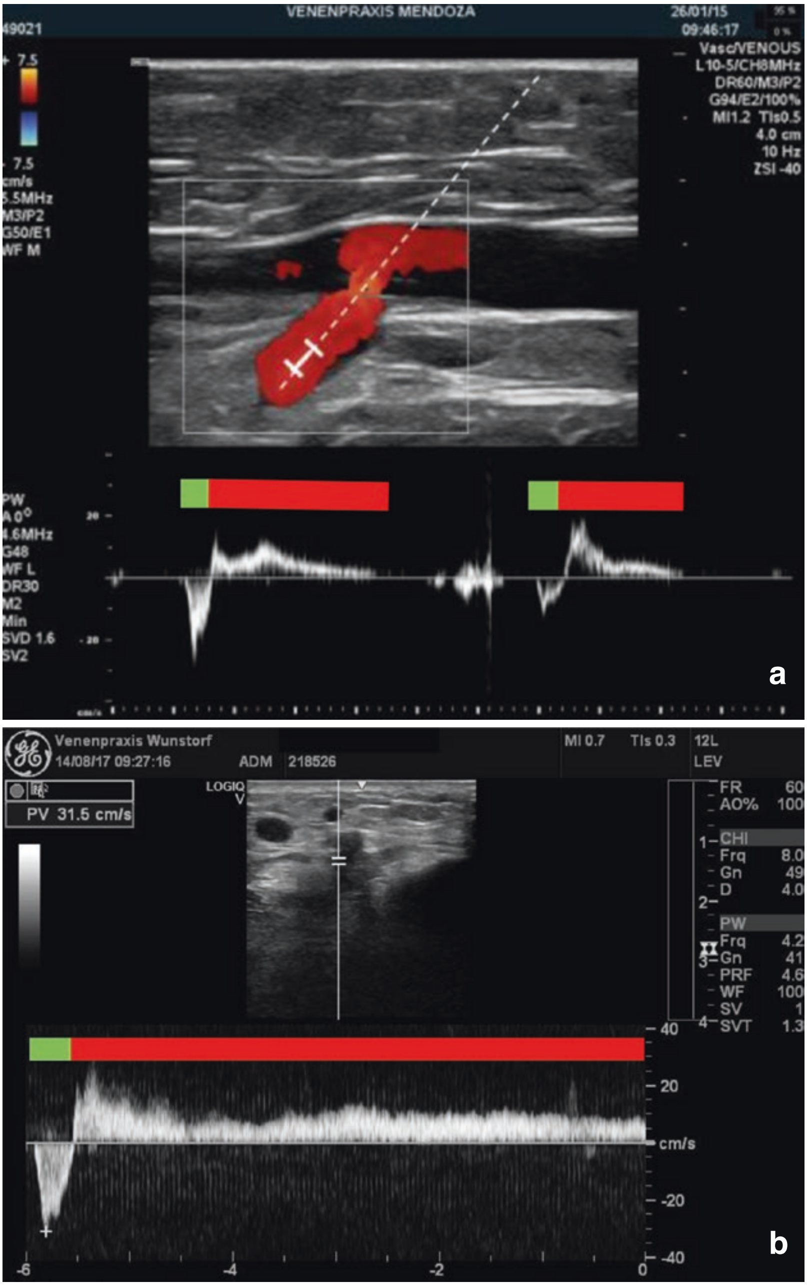

Fig. 4.33 Perforating vein as a reflux source: (**a**) Longitudinal representation of the GSV at the inner thigh. The proximal GSV (to the left of the image) is competent; the distal GSV (at the right of the image) has reflux. In colour the perforating vein and the distal GSV are shown to be refluxing (red) in diastole. On the bottom, the PW measurement in the perforating vein is added. Note that during systole the flow is antegrade (inwards) and during diastole a reflux is seen outwards and then downwards. (**b**) Refluxive perforating vein at the calf: the cross-section at the medial calf shows a paratibial perforating vein with antegrade (inward) flow in systole and long-lasting, retrograde flow in diastole. This is not a common finding in the calf

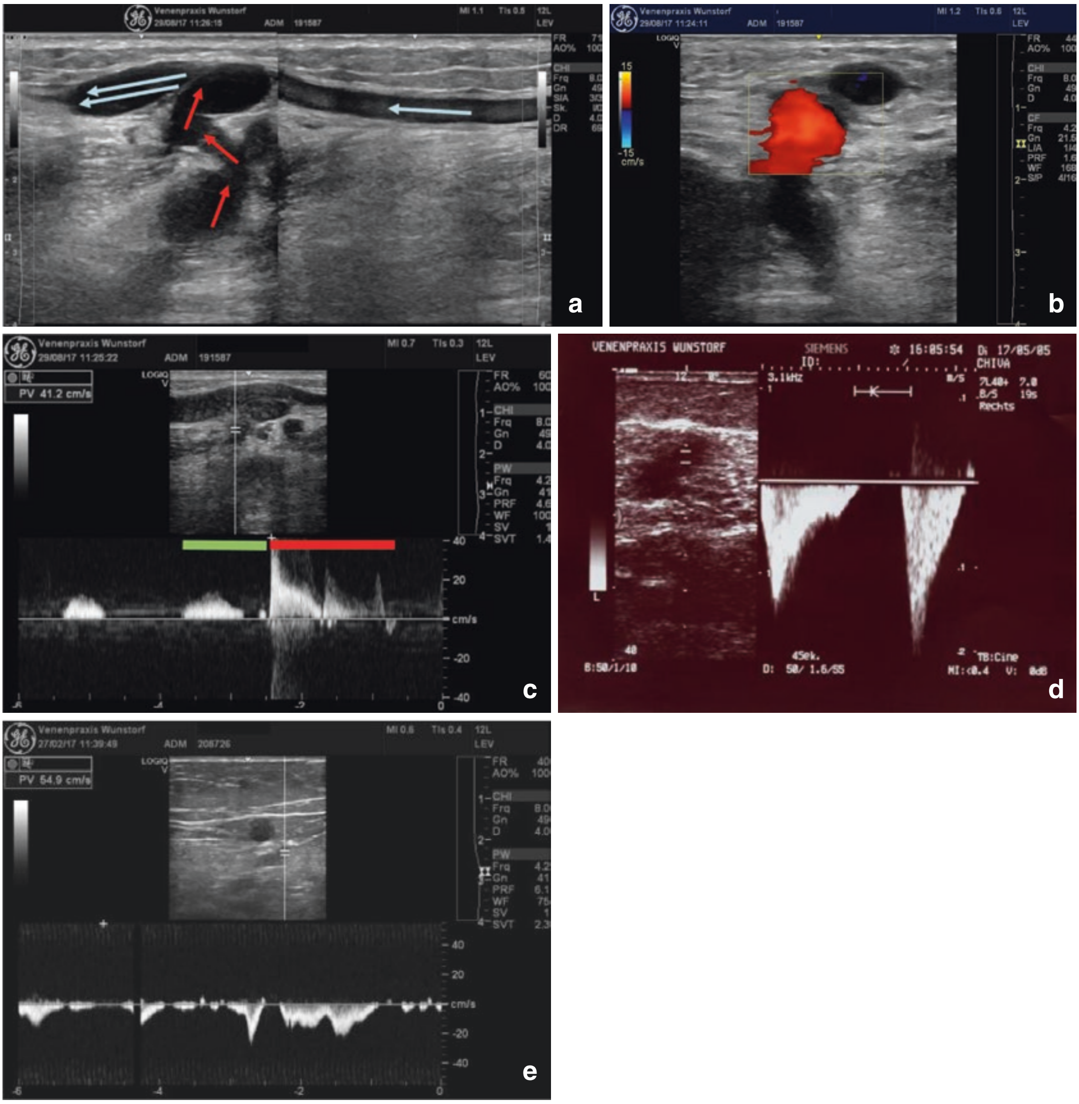

Fig. 4.34 Perforator as part of a bypass for the deep venous system after thrombosis (open vicarious or bypass shunt). (**a**) Longitudinal image or the proximal inner part of the calf with GSV. On the right part of the image, the distal GSV is draining physiologically upwards (one blue arrow). On the left part of the image, red arrows show the blood flow through the paratibial perforating vein. The GSV on the left part of the image is dilated segment, also with antegrade flow. This is required to transport the additional blood entering the GSV from the perforating vein as part of a deep venous bypass. (**b**) Cross-section of the proximal calf of the same patient with the tibia at the left border of the image. The GSV is to the right and is being filled with red (refluxing) blood from the paratibial perforating vein during muscular systole. (**c**) Measurement using PW mode in the perforating vein in systole and diastole. In both phases, incompetent flow is observed from deep vein to superficial, filling the proximal GSV (same patient as **a** and **b**). (**d**) Draining perforating veins. Non-terminalising perforating vein at the mid-thigh with draining (inwards) flow in systole and diastole. (**e**) Terminalising perforating vein at the calf with draining (inwards) flow in systole and diastole. With manual compression of the calf over lax muscles during "systole", an outward flow can be seen, which can cause confusion. (**d**) With permission by [5]

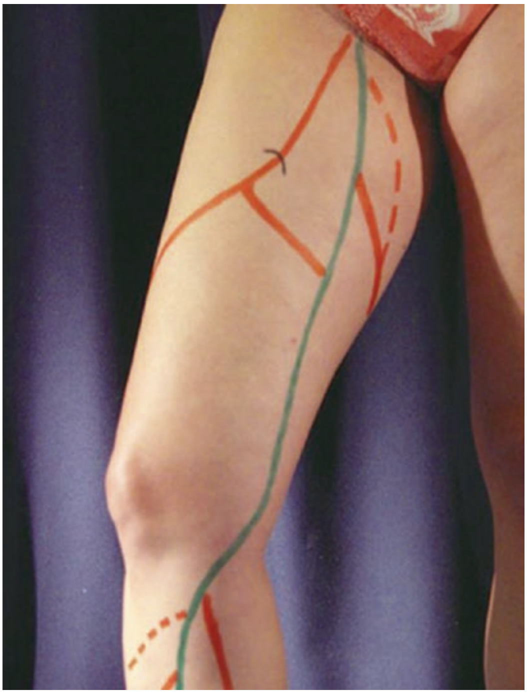

Fig. 4.35 Major tributaries of the GSV, at the thigh: anterior and posterior accessory saphenous veins (red) demonstrating variations in their termination with the great saphenous vein (green). The dotted line marks the alternative course of the posterior accessory saphenous vein into the confluence of superficial inguinal veins. The black mark indicates where the anterior accessory saphenous vein leaves the fascial compartment of the great saphenous vein and becomes epifascial. Distal of this point, there is very often a connecting vein between the anterior accessory saphenous vein and the great saphenous vein. At the calf, the posterior accessory arch vein plays an important role in the drainage of refluxing veins towards the calf perforating veins (red dorsal line). From this vein a communicating vein towards the SSV is possible. With permission by [5]

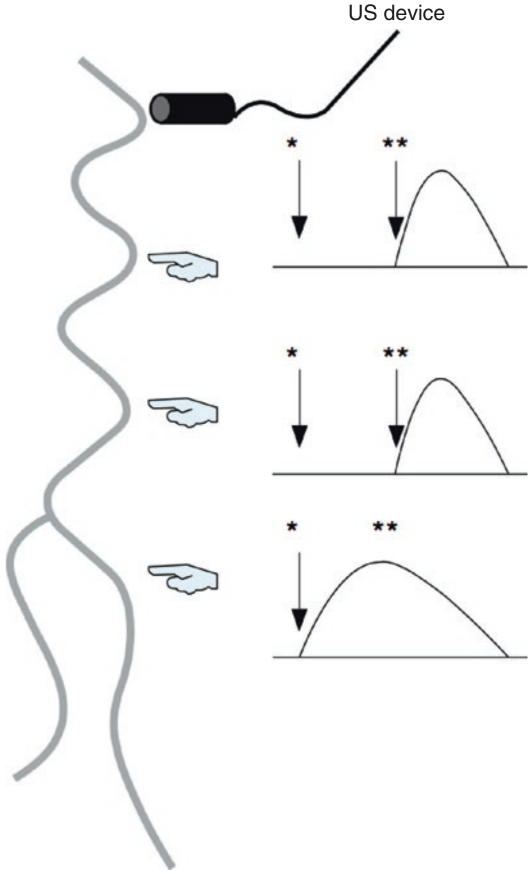

Fig. 4.36 Diagram of the examination technique used to determine the site of important drainage points. The probe is placed at the upper end, and the hands indicate the points at which the vein is compressed with the finger. The curve on the right shows the velocity profile in each case after muscle contraction (rising the toes). One star (*) shows the beginning of the muscular diastole (lowering the toes); two stars (**) show the moment of the release of the digital compression. For further explanations please see the text. With permission by [5]

mon femoral vein is examined together with the SFJ. It can be seen in cross-section and in longitudinal view. In the popliteal fossa, the popliteal vein structure and flow pattern is best seen in longitudinal view. However, a cross-section is best to rule out a thrombosis (see Fig. 4.37). In order for reflux to arise from the deep vein into a superficial vein, the reflux must start in the deep vein. This can lead to the incorrect interpretation, that also the deep vein has also reflux (see Fig. 4.38) [14, 15]. Thrombosis or post-thrombotic changes are visualised as hyperechoic structures inside the vein (see Fig. 4.39).

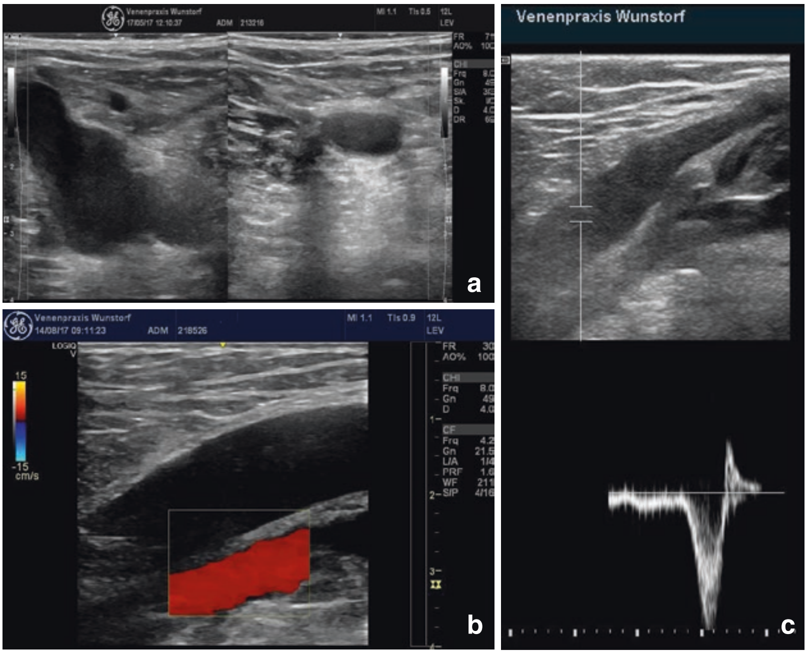

Fig. 4.37 Normal deep veins. (**a**) Compression ultrasound to rule out the presence or absence of a thrombus. This should be done and documented before any treatment of the superficial vein is performed. On the left part of the image is cross-section without compression, where the common femoral vein and sapheno-femoral junction, as well as tributary (blue arrows) and common femoral artery (red arrows) are seen. On the right part is a cross-section at the same place with compression. Only the artery lumen remains (red arrows). The veins have been completely compressed, demonstrating absence of thrombotic material. (**b**) Longitudinal representation of a normal popliteal vein and artery (artery with red blood flow). The vein has smooth walls without bulges or thickenings. (**c**) Flow curve in a normal popliteal vein, measured slightly ahead of the knee crease

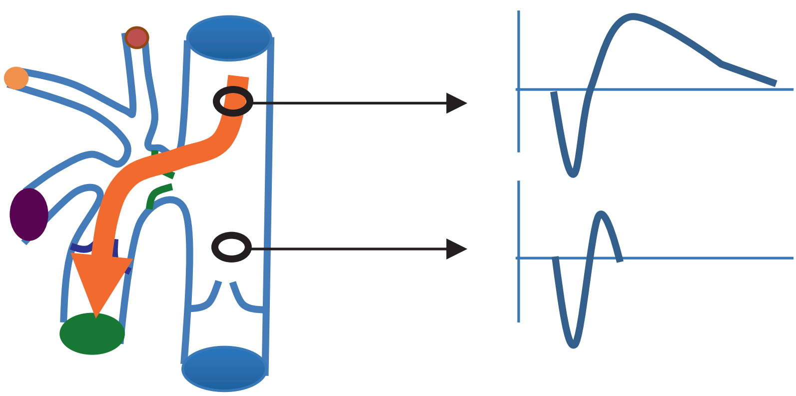

Fig. 4.38 Flow in the deep vein (CFV) above and below the sapheno-femoral junction in a patient with terminal valve incompetence (Compare Fig. 4.13). In the CFV the flow curve shows a reflux in diastole. This is the flow from the deep vein draining pathologically into the GSV when there is superficial vein incompetence. After treating the superficial vein incompetence, the reflux in the deep vein will stop, because there will be nowhere for the blood to go. Distal to the junction, the flow is normal in the deep vein. With permission by [18]

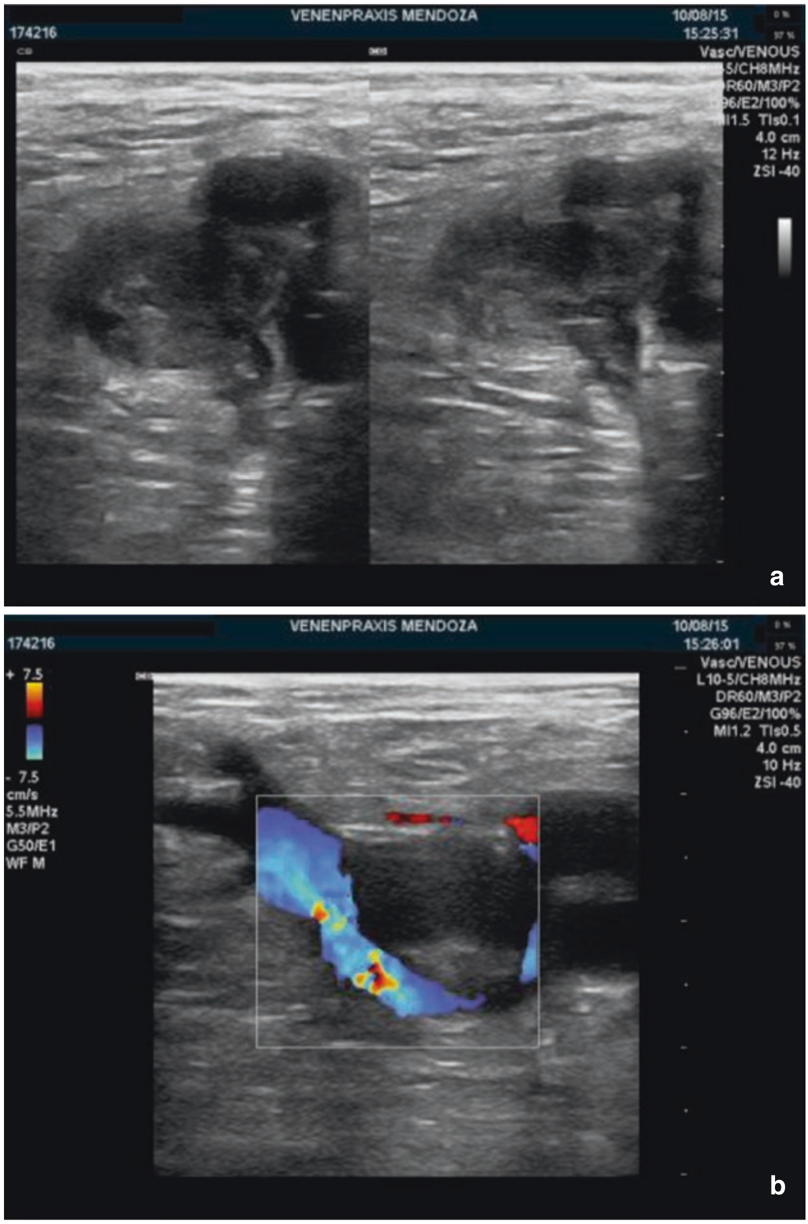

Fig. 4.39 (**a**) Cross-section of the left groin without compression (left) and with compression (right). (Superficial) femoral artery, red arrows; profound femoral artery, orange arrows; CFV, blue arrows. With the compression, the deep vein is not compressed, demonstrating the presence of a thrombus. (**b**) Colour-coded ultrasound of the same site without any manoeuvre. Permanent blood flow from the GSV into the CFV, around the thrombus

4.10 A Routine Exploration

Deep veins can be examined in the lying, sitting or standing position.

A routine examination of the superficial veins should be performed in the standing position. Every specialist is free to develop his standards, but the routine should be always the same to avoid forgetting a part of the exploration.

The following routine is an example:

- Start in the right groin with in B-mode, colour and PW flow:
  - The common femoral vein (also with compression)
  - The artery
  - Sapheno-femoral junction with all its branches

- Follow the GSV down to the ankle, measuring:
  – The diameter at the proximal thigh
  – Blood flow at proximal thigh
  – The site of any calibre changes
  – Exploring flow in visible tributaries and perforating veins
- Turn the patient with the back to the examiner and explore the knee crease in B-mode and Duplex:
  – Popliteal vein (also with compression)
  – Popliteal artery
  – Sapheno-popliteal junction and Giacomini vein, if present, follow it up to the thigh
- Follow the SSV down to the ankle, measuring:
  – The diameter and blood flow below the knee
  – The site of any calibre changes
  – Flow in visible tributaries and perforating veins
- Look at any additional visible varicose veins and examine their origin and draining pathways

4.10.1 Questions to Be Answered at the End of the Examination: Great Saphenous Vein

Morphology

- Is there any anomaly of the sapheno-femoral junction?
- Is an aneurysm present?
- Is the great saphenous vein visible in the fascial compartment throughout its length?
- What is its diameter at the standardised point 10–15 cm below the junction?
- Are there any changes in saphenous calibre?
- Is its course typical in relation to topographical anatomy?
- Is there a duplication or aplastic segments present over part of its course?
- Is there evidence of thrombosis or post-thrombotic changes?
- Are any dilated tributaries or perforating veins apparent in the course of the great saphenous vein?
- Are there any pathological soft-tissue changes surrounding the great saphenous vein?
- Has all or part of the saphenous vein been treated before?

Function

- Is there reflux through the sapheno-femoral junction?
- Is the terminal valve competent?
- Is the preterminal valve competent?
- Are the superficial inguinal tributary veins competent (including AASV)?
- Is there reflux in the great saphenous vein?
- Where is the proximal reflux source?
- Are tributaries or perforating veins involved in the recirculation circuit?
- Does the reflux leave the great saphenous vein by a tributary or a perforating vein?
- Are one or more segments of the vein refluxing?
- How is the draining pathway of the saphenous vein?

4.10.2 Questions to Be Answered at the End of the Exploration: Small Saphenous Vein

Morphology

- Does the small saphenous vein join the popliteal vein?
- Is an aneurysm present?
- At which level is the sapheno-popliteal junction in relation to the posterior knee crease?
- Is the small saphenous vein connected to muscle veins in the region of the junction?
- Does a thigh extension of the small saphenous vein exist?
- Does it become a Giacomini vein?
- Is there any anomaly in the junction of the small saphenous vein?
- What is its diameter at a standardised point, 5 cm below its junction?
- Are there any sudden changes in calibre?
- Is its course typical or does it deviate or duplicate?
- Does any segment have superficial vein thrombosis or post-thrombotic alteration?

- Are any dilated tributaries or perforating veins along the small saphenous vein's course?
- Are there any remarkable findings in the tissues surrounding the small saphenous vein?

Functional

- Is there reflux in the junction of the small saphenous vein refluxing?
- Is the thigh extension or the vein of Giacomini competent?
- Are the muscle veins competent?
- Does the small saphenous vein have reflux?
- Where does the proximal reflux source arise from?
- Does the reflux leave the small saphenous vein by a tributary or a perforating vein?
- Have one or more segments demonstrated reflux?

4.10.3 Questions to Be Answered at the End of the Exploration: Perforating Veins

Morphology

- Are there any dilated perforating veins in the course of the great and small saphenous veins?
- Are there any visible perforating veins in other typical locations, such as the posterior arch vein and the back or lateral side of the thigh or calf?
- If so, is it a muscle perforating vein (connection between deep vein, muscle vein via perforating vein to a superficial vein), and is there a posttraumatic cause in the case of dilation?
- Have the perforating veins suffered post-thrombotic damage?
- What is their diameter?

Functional in perforating veins of large diameter (>3 mm):

- Is the perforating vein incompetent and which is the reflux source?
- Is the perforating vein a re-entry point with draining flow?
- Is the reflux in the perforating vein systolic (bypassing shunt) or diastolic (filling varicose veins)?

4.11 Investigation After Treatment of Veins

Duplex ultrasound not only provides an evaluation of the patient prior to intervention but also a follow-up after the treatment. This is important to monitor the success of the intervention, recognise side effects or complications and determine the pathogenesis behind possible recurrences. Historically, phlebography was only applied when there were visible recurrences, but this test is invasive. Ultrasound does not harm the patient yet provides a comprehensive quality control instrument for the physician.

A basic issue when performing a follow-up is a good preoperative documentation of the findings. This is the only way to evaluate technical or tactical errors if the expected result is not achieved.

This chapter focusses on the duplex findings of the veins after saphenous sparing surgery is commented.

The hallmark of effect in all saphenous sparing intervention is the reduction in calibre of the saphenous veins in the follow-up [14, 15, 23].

4.11.1 Flow Patterns After CHIVA

In case of CHIVA 2 after surgery there are two possibilities:

- Competent saphenous vein (complete success of the strategy in one step)
- Same or less reflux in saphenous vein with drainage either through a perforating vein or a new tributary

When the reflux point has been interrupted, a distinction must be made between incompetent perforating veins or junctions.

After interruption of a perforating vein: If the perforating vein was the only reflux source, after its interruption the expected flow in the GSV or SSV will be antegrade in its whole length.

After **interruption of a junctio**n: Here the flow in the saphenous vein will be less than before the intervention but still footwards ("deflusso" or a deflux) (see Sects. 6.3.4.1 and 6.14.3 and Fig. 4.40). This blood flow originates from the physiologic blood flow from the tributaries. When the proximal exit point of the saphenous vein is closed, this tributary blood has to flow downwards to meet the next perforating vein and drain into the deep vein. The amount and velocity of this flow is very small. Often it appears after some delay following a provocation manoeuvre.

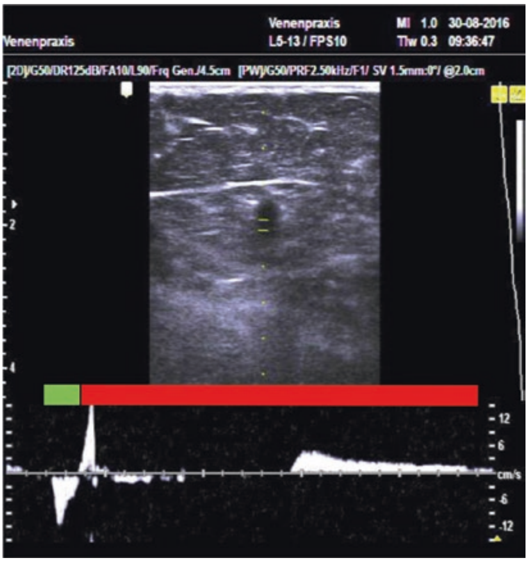

Fig. 4.40 Cross-section of the GSV at the mid-thigh after a crossotomy. Muscular systole (green line) with antegrade flow, followed by a short retrograde flow in diastole representing valve closure. A few seconds later, a very slow downwards flow is seen. It represents the drainage of the tributaries through the saphenous vein

This downwards flow is often confused with a persistent or new reflux when comparing crossectomy alone with crossectomy and stripping [24]. If a patent GSV is left in situ and connected with tributaries and perforating veins, the only possible flow direction is down, towards the lower perforating vein, as upwards flow is not possible, when this exit has been closed. Without this drainage pathway, the complete GSV would close by thrombosis after the intervention.

4.11.2 Flow Patterns in GSV After ASVAL

After the mini-phlebectomy of the varicose reservoir, the reflux in the great saphenous vein will automatically be lesser or even abolished. Depending on the preoperative situation of the saphenous vein reflux, we will find one of the following flow possibilities (see Table 4.3).

Table 4.3 Postoperative flow in GSV depending on the preoperative flow pattern

Preoperative	Postoperative after ASVAL
Segmental reflux in GSV without incompetence of the junction	The GSV will be competent
Competent terminal valve, incompetent preterminal valve, no draining perforating vein on GSV	The GSV will be competent in about 95% of cases (compare Fig. 6.43)
Competent terminal valve, incompetent preterminal valve, draining perforating vein on GSV	The GSV will have little reflux, draining through the perforating vein on the GSV. This situation can remain stable for years without clinics or cosmetic complaints (compare Fig. 6.41)
Incompetent terminal and preterminal valve and no draining perforating vein on GSV	The GSV can be competent or a tributary or draining perforating vein can develop a recurrent reflux in the GSV (compare Fig. 6.17b)
Incompetent terminal and preterminal valve and draining perforating vein on GSV	The GSV will have little reflux draining through the perforating vein on the GSV. This situation can remain stable for years without clinics or cosmetic complaints

4.11.3 Flow Patterns After Extraluminal Valvuloplasty

After the extraluminal valvuloplasty, the GSV is expected to be competent (see Chap. 13). The refluxing tributaries, if left in situ, will no longer be fed retrogradely by refluxing blood from the deep vein and will reduce their calibre. Alternatively, they will be fed with blood from the distal, antegrade flowing GSV (forming a shunt type 2 in this case).

If the valvuloplasty fails, two possible findings can be expected:

- Thrombosis of the proximal GSV causing a complete or partial obstruction of the saphenous vein till the next large perforating vein
- Reduced reflux in the GSV through a smaller SFJ

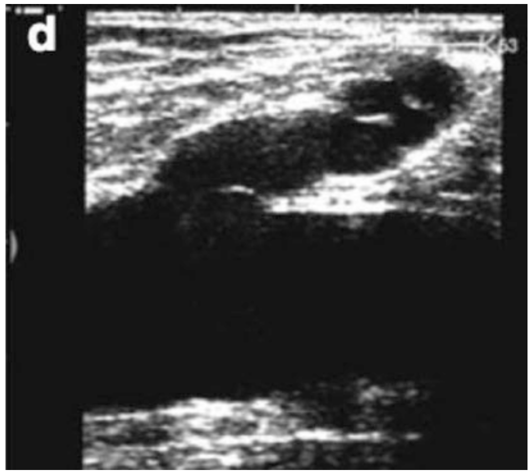

Fig. 4.41 Longitudinal representation of the SFJ: after ligation of the great saphenous vein approximately 2 cm distal to the SFJ in the context of a stripping procedure. The valve can be seen at the sapheno-femoral junction demonstrating that the vein has been left in situ. Typically, the formation of large convoluted venous tributaries arising from the distal end of the stump can be observed. With permission by [5]

4.11.4 Analysing Technical Errors

Technical errors refer to the operating technique. There are lots of possible errors if a crossotomy is not performed correctly, like the errors also known from the classical crossectomy. Leaving a stump is always a technical error leading to recidives (see Fig. 4.41).

At the popliteal junction, surgery is much more complex than in the groin region. If a Giacomini vein is present, the "stump" of the SSV is washed by this vein and therefore the stump may act as a beneficial draining pathway. Nevertheless, a reflux can still arise from this proximal segment of the SSV if a tactical error occurred, like the interruption of the junction when there is systolic reflux (see Sect. 4.11.5).

After performing CHIVA 2, a recurrence can arise at the site of the interruption if a non-flush ligation of the tributary is performed at the level of the saphenous vein (see Fig. 4.42). The consequence is either a matting or a new tributary with reflux. The same can happen after ASVAL, in case the reflux load after ablation of the reservoir in the GSV is large.

4.11.5 Analysing Tactical Errors

A tactical error occurs when the preoperative flow pattern is not properly analysed. This can happen in every strategy, but in CHIVA it will be noticed immediately, as the pathways are left in situ and not obliterated or removed. If the reflux source is not eliminated, the reflux path will persist and it will look like no change after intervention. Alternatively, if the system is interrupted without leaving a good drainage pathway, a non-drained situation will provoke early matting through little reticular veins. On ultrasound, the calibre of the GSV will not decrease.

The classical tactical error in CHIVA is to perform a crossotomy, which is a ligation of the GSV between the tributaries and the deep vein at the ostial level, in patients with pelvic reflux, also called para-ostial reflux. The reflux source will remain untouched and continue to fill the GSV (see Fig. 4.43). Not being aware of the fact that about 30% of patients have an isolated or combined para-ostial reflux (see Table 4.1) and applying a crossotomy without interruption of the refluxive tributary to all patients with SFJ reflux

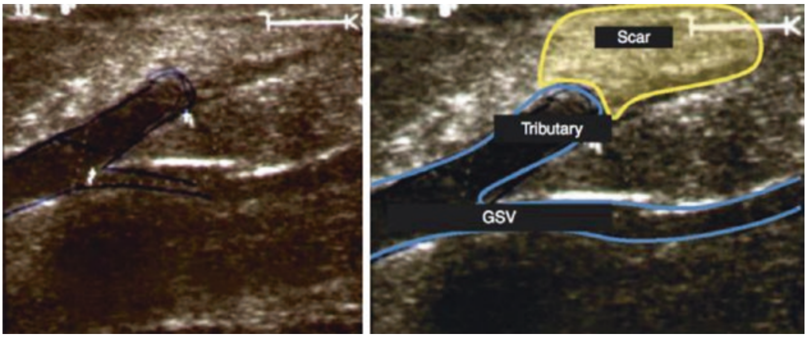

Fig. 4.42 Longitudinal representation of the inner aspect of the proximal thigh after surgery (CHIVA 2: Interruption of a tributary at the GSV). Left native image. Right annotated image: the scar (yellow) was not at the level of the junction between the tributary and the GSV, but distally. This was not a flush ligation but left a stump of proximal tributary. This resulted in a clinical recidive, with a visible tributary on the skin and persistence of reflux in GSV. With permission by [5]

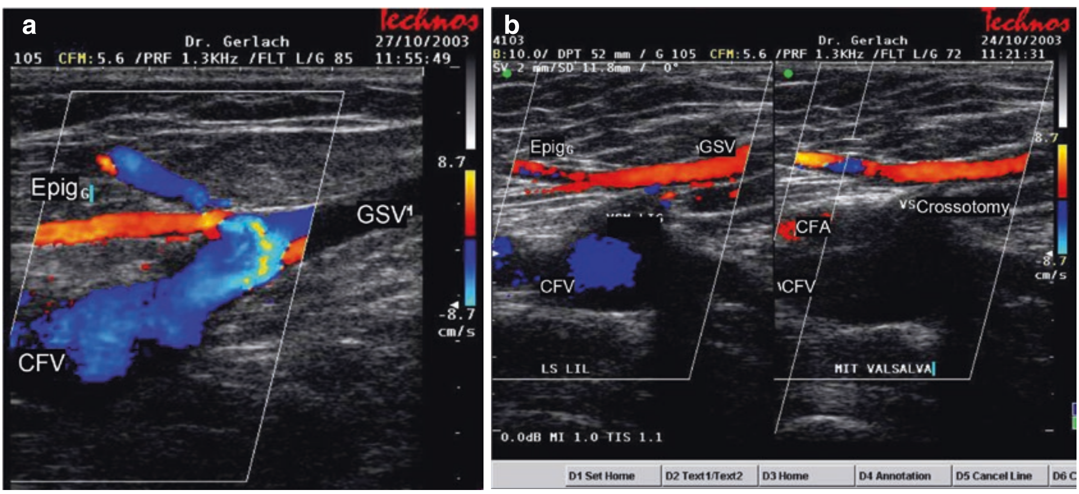

Fig. 4.43 (**a**) Preoperative image in longitudinal view of the SFJ in a patient with a refluxing epigastric vein. (**b**) Postoperative image of the same SFJ after crossotomy with persistent reflux from the epigastric vein into the GSV. Tactical error. From Dr. Horst Gerlach, Mannheim, with kind permission

would lead to reflux persistence due to tactical error in 30% of all treated patients!

Another tactical error is to close an open bypassing shunt. This will induce recurrences at the site of the ligation, like in the open bypassing shunt described in Sect. 3.9.3, if the Giacomini vein or the SSV is interrupted in the knee crease. The recurrence will appear soon after intervention with lots of new vessels through the scar.

4.11.6 Assessment After Endoluminal Treatment of the Junction

After endoluminal closure of the GSV or the SSV in the context of CHIVA, the first follow-up should be at 1 week to rule out a deep vein thrombosis and also to make sure the superficial vein has been closed.

In cross-section, the deep vein at the level of the SFJ is visualised and a compression ultrasound performed to make sure in the deep vein there is no thrombus. The SFJ is examined looking for the proximal end of the heat-induced closure of the vein. This should look like a superficial vein thrombus. This usually ends at the confluence of a tributary, which acts to wash out the SFJ. An "EHIT" (endoluminal heat-induced thrombus) occurs when thrombotic material from the heat closure is encroaching into the deep vein lumen. This has to be excluded. Although the natural history is usually benign, anticoagulation for 6 weeks is often recommended.

The flow in the proximal GSV is assessed with colour-coded duplex. No flow is expected beyond the SFJ in the proximal part of the GSV. This part of the GSV has to be uncompressible in cross-section.

One possible failure of endoluminal CHIVA is that the reflux from the deep vein continues through the terminal valve and into the anterior accessory saphenous vein. This pathway was not refluxing prior to the intervention (in this case, it would have been treated). But for unknown reasons, in some cases a preoperatively non-visible or very thin AASV gets incompetent and feeds the distal GSV with reflux via the communicating vein (see Sect. 6.15.2).

It is important to inform the patients about this fact in case of choosing endoluminal junction treatment prior to intervention. The AASV may need to be closed with either ultrasound-guided sclerotherapy or an endoluminal ablation.

4.12 Documentation of the Findings

The findings of the examination have to be documented as images and as a description of the venous pathways.

The images have to include:

- Compression ultrasound of the deep veins at least at the common femoral vein and popliteal vein site, as well as a flow curve inside these veins prior to therapy. This is important to make sure no pathology was present before the intervention. If a prior pathology is present, its documentation demonstrates that this wasn't provoked by the intervention.
- Diameters of the pathological veins: GSV at the junction and at proximal thigh (10–15 cm distally from the groin) measured in cross-section, SSV below the knee crease.
- A flow curve inside the pathological vein segments in PW mode to demonstrate the fact that there was a reflux prior to intervention.

The description might be with a drawing or as a text (see Sect. 11.2.3 and Fig. 11.4). It is always helpful after the intervention to determine exactly which situation was found before the treatment. This is not only important to analyse possible tactical errors in case of failure or for a scientific investigation in larger series, but it will also help to defend yourself in a legal situation.

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