Haemodynamic changes of the deep vein system of the leg after surgery of the incompetent great saphenous vein

J. Kostecki[1]; M. Zaniewski[1]; T. Urbanek[2]; A. Dorobisz[3]; E. Majewski[1]; U. Skotnicka-Graca[1]

[1]Department of Surgery, Medical University of Silesia, District Specialist Hospital, Tychy; [2]Department of General and Vascular Surgery, Medical University of Silesia, Katowice; [3]Department of Surgery, Vascular Surgery, Wroclaw

Keywords

Varicose veins, deep vein incompetence, reflux, stripping, Doppler ultrasound

Summary

Surgical treatment of chronic venous disease primarily aims to restore the normal haemodynamic conditions in the venous system. The objective of the study was an assessment of the influence of incompetent saphenous vein removal on the haemodynamical changes within the venous and arterial system of the operated extremity. Patients, materials, methods: The study utilised a group of 50 patients presenting with varicose veins (C2 according to CEAP classification) and great saphenous vein incompetence selected for saphenous vein stripping. In all patients, duplex Doppler examination of femoral and popliteal veins as well as femoral and popliteal arteries was performed before surgery, on the first postoperative day and 30 days after surgery. Results: After the removal of an incompetent great saphenous vein, a statistically significant increase in the minute volume flow in the femoral (p = 0.0004) and popliteal veins (p = 0.0011) was observed. Following saphenous vein stripping, a statistically significant reduction of the venous reflux time in the deep vein system was also observed in the common femoral, femoral and popliteal veins, as compared to a pre-operative examination. Postoperatively, normalisation of the venous reflux time was achieved in 36–40% of patients from the group with concomitant deep vein system incompetence. As far as the arterial system is concerned, an increase in the volume flow in the femoral (p = 0.0463) and popliteal arteries was observed, but statistical significance was not achieved in the latter (p = 0.2912). Conclusion: The flow in the deep vein system increases after the removal of the incompetent great saphenous vein. In some patients with an incompetent deep vein system, venous reflux time returns to normal after the incompetent saphenous vein has been removed.

Schlüsselwörter

Stammvarikosis, Insuffizienz der tiefen Venen, Reflux, Stripping, Doppler-Sonographie

Zusammenfassung

Krampfadern als Folge der Insuffizienz der Vena saphena magna sind die häufigste Manifestation der chronischen venösen Insuffizienz. Die Koexistenz von suprafaszialer und tiefer Venensysteminsuffizienz beeinflusst Lebensqualität und Ergebnisse chirurgischer Eingriffe. Die Persistenz eines signifikanten Refluxes im Bereich des tiefen Venensystems vergrößert das Risiko eines Krampfaderrezidivs und der damit verbundener Komplikationen. Laut früherer Untersuchungen kann die Beseitigung des Refluxes der suprafaszialen Venen zur hämodynamischen Verbesserung im tiefen Venensystem beitragen. Die chirurgische Behandlung der chronischen venösen Insuffizienz beruht primär auf Wiederherstellung der physiologischen Verhältnissen im venösen System. Das Ziel dieser Studie war die Beurteilung der Auswirkung der Entfernung der inkompetenten V. saphena magna auf das gesamte venöse und arterielle System der operierten Extremität. Patienten, Methoden: An der Studie nahmen 50 Patienten mit venöser Insuffizienz (C2 nach CEAP) teil, die wegen hochgradiger venöser Insuffizienz zum V.-saphena-Stripping vorgestellt wurden. Bei allen Patienten wurde eine Insuffizienz 3. Grades (Hach) der Vena saphena magna festgestellt. Bei einigen Patienten stellte man eine gleichzeitige Insuffizienz des tiefen Venensystems im femoralen und poplitealen Venenbereich fest: $C_2E_pA_{spd}P_{r2,3,5,13}$ bei 4 Patienten, $C_2E_pA_{spd}P_{r2,3,5,13,14}$ bei 7 Patienten, $C_2E_pA_{spd}P_{r2,3,5\ 14}$ bei 15 Patienten, $C_2E_pA_{sp}P_{r2,}$ bei 10 und $C_2E_pA_{sp}P_{r\ 2,3,5}$ bei 14 Patienten. Bei allen Patienten wurde eine Duplex-Doppler-Untersuchung der femoralen und poplitealen Venen und Arterien präoperativ durchgeführt. Als sonographische Verlaufskontrolle wurde dies in gleicher Weise am 1. und 30. postoperativen Tag wiederholt. Ergebnisse: Nach operativer Entfernung der insuffizienten V. saphena magna wurde eine statistisch relevante Zunahme des Blutflusses in der femoralen (p = 0,0004) und poplitealen (p = 0,0011) Vene beobachtet. In deren Folge ist festzustellen, dass das eine statistisch signifikante Reduktion des venösen Refluxes im Bereich des tiefen Venensystems im Vergleich zum präoperativen Status bewirkt. Das Phänomen betrifft das femorale und popliteale Venensystem. In der untersuchten Kohorte wurde bei 36–40% Patienten eine Normalisierung der venösen Refluxzeit auch bei begleitender tiefen Veneninsuffizienz erreicht. Hingegen wurde eine sta-

Correspondence to:
Jacek Kostecki MD PhD
Department of Surgery
District Specialist Hospital
ul. Edukacji 102, 43–100 Tychy, Poland
Tel. +48/32/325 42 97
E-mail: kosteckj@op.pl

Hämodynamische Veränderungen im tiefen Venensystem der unteren Extremität nach Stripping-Operation der inkompetenten Vena saphena magna
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tistisch irrelevante Zunahme des Blutflusses im arteriellen System erfasst. Schlussfolgerung: Nach Entfernung der insuffizienten V. saphena magna erhöht sich der venöse Blutfluss im tiefen Venensystem. Sogar bei einigen Patienten mit Insuffizienz des tiefen Venensystems kam es nach Entfernung der (insuffizienten) V. saphena zur Normalisierung der venösen Refluxzeit.

One of the most common manifestations of chronic venous disease are lower extremity varicose veins, which are often related to great saphenous vein incompetence. The coexistence of deep and superficial vein system insufficiency can have a significant influence on both the patient's quality of life and the surgical treatment's long-term results.

The presence of a haemodynamically significant reflux in the deep vein system increases the risk of the recurrence of varicose veins and venous ulcers (1). On the other hand, according to some authors, eliminating the reflux in the superficial vein system can result in haemodynamical improvement and reduce the degree of the deep vein system insufficiency (2–5).

Great saphenous vein stripping remains one of the most common procedures in patients with varicose veins. Currently, due to technical progress, an ablation of the saphenous vein can be performed by minimally invasive methods such as endovenous laser or radiofrequency ablation (6).

In this study, we evaluated how the removal of the incompetent great saphenous vein (by stripping) influences the haemodynamic transformation within the lower extremity deep vein system.

Patients, materials and methods

The prospective study comprised a cohort of 50 patients aged between 14 and 70 years (mean 50 years) with lower extremity primary varicose veins who qualified for stripping of the great saphenous vein according to van der Stricht. In all patients, clinical stage C2 was diagnosed according to the CEAP classification, and an incompetence of the sapheno-femoral junction and the great saphenous vein trunk (grade III according to Hach) were also diagnosed. In some patients, the presence of concomitant deep vein system reflux (>0.5 s) in the ultrasound (US) examination was found for both femoral and popliteal veins:

- $C_2E_pA_{spd}P_{r2,3,5,13}$ for 4 patients,
- $C_2E_pA_{spd}P_{r2,3,5,13,14}$ for 7 patients,
- $C_2E_pA_{spd}P_{r2,3,5\ 14}$ for 15 patients,
- $C_2E_pA_{sp}P_{r2,3}$ for 10 patients and
- $C_2E_pA_{sp}P_{r\ 2,3,5}$ for 14 patients.

The main exclusion criteria were: diabetes mellitus, peripheral atherosclerotic obliterative diseases, recurrent varicose veins, treatment with vasoactive drugs, acute or previous thrombosis in the deep or superficial vein system, atrial fibrillation or other important arrhythmias, acute or chronic circulatory failure or intra-abdominal hypertension (ascites, obesity, pregnancy).

The control group consisted of 10 volunteers (mean age 49 years) without incompetence of the saphenous vein and without manifestations of any chronic venous disease.

All study participants underwent duplex Doppler examination of the lower extremity venous and arterial system performed by the same experienced investigator. They were examined three times: before surgery, the day after and 30 days after stripping.

The GE Loqic Book XP ultrasound with a linear 5–7.5 MHz probe was used. All study participants were examined after at least 30 min of rest. Each time, prior to the examination, blood pressure and heart rate were taken, all consecutive examinations were performed with the same or approximate similar values for these parameters.

Deep vein system reflux was measured in the standing position at the level of the femoral vein above the sapheno-femoral junction, at the halfway point of the thigh and in the popliteal vein above its division. To standardise the compression needed to elicit a reflux wave, a device capable of applying automatic pneumatic compression was used. The venous reflux time in seconds was measured from the reflux wave tracing in the pulsed Doppler presentation.

The measurement of the mean flow velocity in the femoral and popliteal veins was performed in the reclining position with the upper body raised to 45°. The mean flow velocity was calculated using the device's software from a 30 s tracing of the pulsed Doppler spectrum wave during easy, regular breathing (to avoid any influence of the respiratory variation of the flow). From the mean flow velocity V_{mean} the minute flow volume V_{flow} was calculated according to the formula

$$V_{flow} = V_{mean} \times P_{area} \times 60$$

where P_{area} is the cross-sectional area of the vessel.

The cross-sectional areas of the femoral and popliteal veins were measured above the sapheno-femoral and sapheno-popliteal junctions using planimetric assessment by outlining the vessel lumen (in transverse, B-mode scans) and utilising the device's software. The measurements were performed three times, the results were averaged.

Apart from deep vein system assessment, the following parameters related to the arterial flow were simultaneously evaluated by means of Doppler ultrasound in the femoral and popliteal arteries:

- minute volume flow,
- Gosling's pulsatility index (PI),
- Puercelot's resistance index (RI) and
- mean velocities.

The measurements were performed in the reclining position by means of vascular application of the device after the appropriate flow pattern had been obtained (duplex Doppler based on pulsed Doppler spectrum analysis).

In all cases, a tight length compression stocking (CS) class 2 was applied for at least 30 days after surgery (none of the patients used the CS before surgery). Also in all cases, the duplex Doppler examination was performed without CS on the examined leg (30 minutes after compression removal). The same compression stocking was applied in the control group during the study period, too.

Statistical analysis was done by Student's t-test, Friedman's test as well as Wilcoxon test for between-time comparisons and Mann-Whitney U test for between-group comparisons. The level for statistical significance was set to $p < 0.05$.

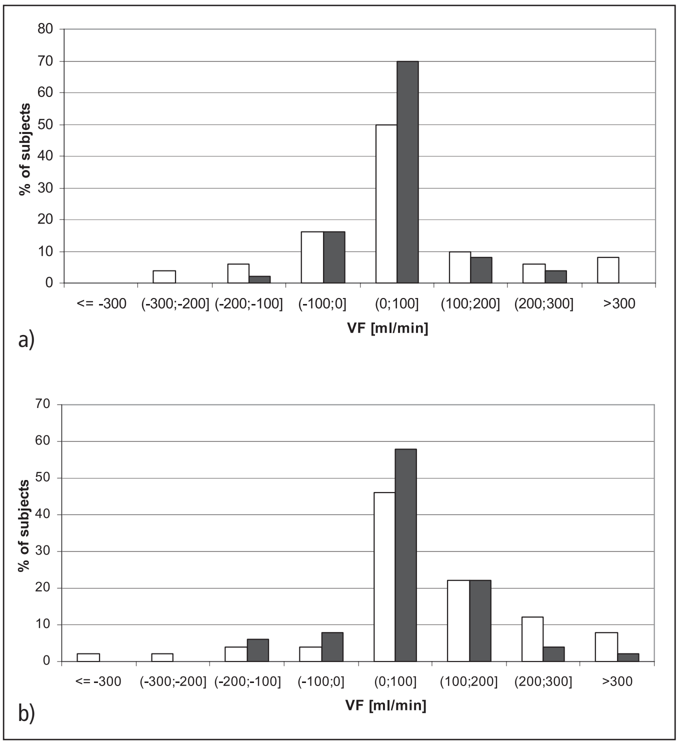

Fig. 1 Minute volume flow (VF) in the common femoral vein (□) and popliteal vein (■) in comparison with the preoperative values **a)** 1st postoperative day; **b)** 30th postoperative day

Results

The mean preoperative minute volume flow in the common femoral veins was 298.7 ± 145 ml/min, and it was 118.51 ± 84.2 ml/min in the popliteal veins. After the removal of the great saphenous vein, a statistically significant increase in the blood flow within the deep vein system was observed. The mean increase in the minute volume flow in the common femoral vein was 66.89 ± 21.14 ml/min on the 1st postoperative day. This is a statistically significant difference compared to the preoperative examination (p = 0.0025) and to the control group (p = 0.0110).

Similar findings were observed on the 30th postoperative day: a statistically significant increase in the minute volume flow of 91.55 ± 21.3 ml/min (mean) was found in comparison with the preoperative measurements (p = 0.0004) and with the control group (p = 0.0143). In the popliteal veins, the increase of the mean minute volume flow was 42.4 ± 9.82 ml/min on the 1st postoperative day and 61.8 ± 13.28 ml/min (mean) at 30 days after surgery. Both of these values reached statistical significance in comparison with the preoperative measurements: p = 0.0006 (1st postoperative day); p = 0.0011 (30th postoperative day) for the patients and with the control group p = 0.0048 (1st postoperative day); p = 0.0038 (30th postoperative day).

The distribution of the postoperative minute volume flow changes in the common femoral and popliteal veins are shown in ▶Figure 1.

The cross-sectional area of the femoral veins at the first examination was 2.03 cm^2. It was significantly higher in the patients than in the control group (p = 0.0317). On the 1st postoperative day, a statistically significant increase by 0.12 cm^2 (p = 0.0072) was observed in the cross-sectional area of the femoral veins. The preoperative values were reached by day 30. The mean cross-sectional area of the popliteal veins at the first examination was 1.38 cm^2 and did not significantly differ the day after the procedure (1.36 cm^2). Both values were significantly higher in patients than in the control group. However, 30 days after surgery, a statistically significant reduction by 0.19 cm^2 (p = 0.0019) in the mean cross-sectional area was found. These values remained at a higher level in the patients than those in the control group (p = 0.0367).

The mean reflux times, when examined preoperatively, were 0.4 ± 0.056 s in the common femoral vein, 0.33 ± 0.045 s in the superficial femoral vein and 0.58 ± 0.07 s in the popliteal vein.

After the removal of the great saphenous vein there was a statistically significant decrease in the venous reflux time in the deep vein system as compared to the preoperative examination (femoral vein above sapheno-femoral junction, p = 0.0002; superficial femoral vein, p = 0.0001; and popliteal vein, p = 0.0005). The mean decrease in the reflux time in the common femoral vein was 0.149 ± 0.047 s on the 1st postoperative day and 0.152 ± 0.049 s at 30 days after surgery. The mean decrease in the reflux time in the popliteal vein was 0.092 ± 0.056 s on the 1st postoperative day and 0.167 ± 0.04 s at 30 days after surgery (▶Fig. 2).

In the patients group, 11 patients had a venous reflux time > 0.5 s in the femoral vein and 15 showed a pathological reflux in the popliteal vein. Assuming that a venous reflux time >500 ms according to many authors (7) is a cut-off value for the deep vein system incompetence, normalisation of the venous reflux time was discovered in 36% of patients with femoral vein incompetence and 40% with incompetent popliteal veins.

No difference was noted in the diameter of the arterial vessels or in the PI indices in both groups as well a in the patients preversus postoperatively. A statistically significant decrease of the femoral artery resistance index was observed only 30 days after surgery (p = 0.0409) but not on the 1st postoperative day (p = 0.7093). Simultaneously, the resistance indices in the popliteal arteries did not differ significantly.

The mean preoperative blood flow in the common femoral artery was 342 ± 161 ml/min. There was no difference in the femoral artery minute volume flow on the 1st postoperative day, but there was a statistically significant (related to the mean velocity values) increase in the blood flow in the femoral artery at 30 days after stripping (414 ± 193 ml/min; p = 0.0463). The volume flow and mean velocities in the popliteal artery also increased, but statistical significance was not reached.

No relevant surgical complications related to the great saphenous vein stripping were noticed, neither wound infections nor haematomas requiring surgical exploration. In all of the cases, the local postoperative tissue swelling resolved within 30 days after the procedure.

Discussion

An ablation of the reflux in the superficial veins can have a positive influence on other components of the lower extremity vein system including perforators and deep veins (2–5). However, despite the increasing knowledge concerning the pathogenesis of chronic venous disease, many questions remain unanswered, especially concerning the various abnormalities found in the venous system.

Kahle et al. showed that the flow in the common femoral vein in patients with lower extremity varicose veins was greater than that in healthy persons (8). Therefore, after the removal of varicose veins it can be expected that the flow within the deep vein system should be decreased, haemodynamic parameters should be improved and blood recirculation should be stopped. Contrary to these suggestions, in our study, a statistically significant increase in the flow within the deep system was found postoperatively. One of the reasons behind this phenomenon may be the fact that under physiological circumstances about 10% of the blood from the extremity is drained by the superficial vein system, and in cases of advanced varicose veins and great saphenous vein incompetence, this volume can differ significantly. After the removal of the great saphenous vein, some of this blood has to flow through the veins of the deep system. While this may account for the flow increase in the popliteal vein or femoral vein below the sapheno-femoral junction, the same phenomenon within the common femoral vein above the sapheno-femoral junction calls for an additional explanation. Why does the flow within this vessel also increase after the surgery? With some simplification it may be assumed that the common femoral vein is the main vessel draining the blood out of the extremity with blood flowing from both deep veins and the great saphenous vein.

Venous outflow depends on arterial inflow to a large extent and both systems have to remain in a state of balance. The mentioned assumptions have become a starting point for an attempt to create a new parameter reflecting the stage of the chronic venous disease. Kahle et al. proposed the VAFI (venous arterial flow index) derived from dividing the minute volume flow in the common femoral vein by the minute volume flow in the common femoral artery. Under physiological circumstances VAFI equals approximately 1.0 and increases above 1.3 in patients with highly advanced chronic venous disease. Preliminary results prove that VAFI correlates with plethysmography parameters of venous incompetence (venous capacity, venous outflow) (9). Kahle's observation is part of the evidence for the interdependence of the venous and arterial systems within the lower extremity. In our study, apart from the increase in the blood flow within the deep vein system, we also discovered an increased mean flow velocity and an increased minute flow in the common femoral artery.

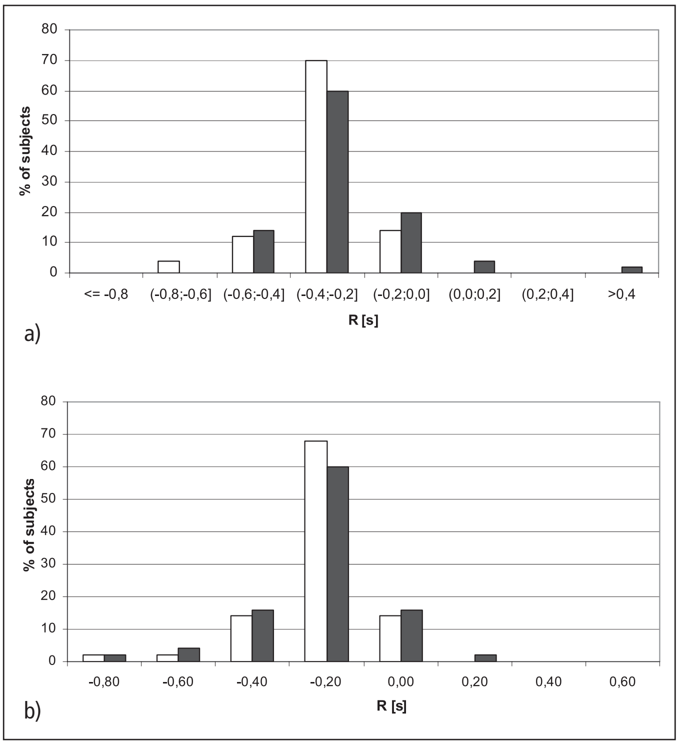

Fig. 2 Reflux time (R) in the femoral vein (□) and popliteal vein (■) in comparison with the preoperative values **a)** 1st postoperative day; **b)** 30th postoperative day

The reason for the increased flow in the arterial system could be the reduced vascular resistance resulting from the decreased intravenous pressure, which in turn is the effect of improved haemodynamic conditions after the removal of the incompetent great saphenous vein. An example of such a system is the study conducted by Delis et al., who showed that for healthy volunteers, the minute volume flow in the popliteal artery decreased in the sitting position compared to the flow in the supine position. Similar relations were found for the mean flow velocity, peak systolic velocity and end-diastolic velocity. However, the pulsatility index significantly increased. Decreased end-diastolic velocity and increased pulsatility index in the sitting position indicate an increased vascular resistance as a result of vascular constriction and elevated intravenous pressure (10).

It is known that physiologically the flow in the lower extremity decreases when the body position changes from supine to sitting and vice versa (11, 12). This is related to a veno-arterial reflex mediated via the sympathetic system, which increases resistance in precapillary vessels in response to increased venous pressure and thereby decreases the capillary flow (13). Venostasis and lowering the extremity below the heart level are factors that trigger the veno-arterial reflex. From a physiological point of view, this reflex is very important because it minimises the pressure in the microcirculation when venous pressure increases (e.g., in a standing position), protecting the capillary bed against the increase in the hydrostatic pressure (13, 14). No consensus exists concerning the evaluation of how chronic venous disease influences the veno-arterial reflex. Some studies demonstrate such a relationship (15, 16) while others do not (17).

Regardless of whether or not the veno-arterial reflex affects the pathophysiology of chronic venous disease, the improved haemodynamic conditions within the venous system entail reduced venostasis, which may further result in an increased arterial flow. This is indicated by our results for the flow in the common femoral and popliteal arteries.

Additional evidence confirming that the elevated intravenous pressure causes decreased flow in the lower extremity is shown in a study conducted by Zang et al., which demonstrated that the venostasis-induced increase in intramuscular pressure (IMP) decreased the perfusion pressure and MBF (muscle blood flow) (18). Another study carried out by Delis et al. supports these hypotheses. It showed that the blood flow increased in the popliteal artery for patients with intermittent claudication, as well as for healthy volunteers after the intermittent pneumatic compression had been applied onto the extremities (19). Intermittent pneumatic compression enforces greater venous outflow from the extremity, resulting in improved haemodynamics and decreased pressure in the venous system. As demonstrated by Delis et al., this causes the volume flow and mean flow velocity to increase, and it also leads to the drop in the pulsatility index in the arterial system (19).

To put it simple, we suggest that a similar situation occurs after removal of the incompetent great saphenous vein: The haemodynamic conditions in the deep vein system improve.

Many studies have confirmed that venous incompetence within the superficial system entails incompetence within the deep system later on (20). This happens as a result of blood refluxing into the deep vein system via perforating veins, which causes an overload of the system and the progressive dilation of veins, leading consequently to valve incompetence. The greater the reflux quantity, the more severe the haemodynamic disorders within the veins. Superficial reflux ablation can offer the chance for the restoration of normal haemodynamic conditions also in the deep vein system.

Plethysmographic evaluations show that after the removal of the incompetent great saphenous vein, the haemodynamic parameters within the operated extremity improve. In the study by Kim et al. conducted on 958 patients who had had great saphenous vein removal, all were found to have subsequent decreases in the venous volume, vein filling index and venous pressure as well as increases in the ejection fraction (21).

Venous reflux time is a parameter characterising venous system competence, i.e., the time span of the retrograde flow until the point of valve closure. Physiologically, in the lower extremity this retrograde flow lasts briefly, just before valve closure, but in the pathological state it is prolonged due to the lack of valves or valve incompetence. The reflux time in different veins varies, likely depending on valves' size, location and number as well as the number and size of tributaries supplying a given vein as well as the elasticity of the vein wall.

Another difficulty can be related to the objective method of reflux measurement. Utilising pneumatic, automatic compression of the lower leg to elicit retrograde flow provides consistent, reproducible conditions for objective evaluation of consecutive measurements. Hence, its application can be proposed as the standard in venous reflux time assessment (22).

In our study, which assessed the effect of great saphenous vein removal on the haemodynamics of flow in the extremity, we discovered a statistically significant decrease in the venous reflux time, which reflects the improved haemodynamic conditions of the venous flow within the operated extremity. The restoration of the reflux time to values regarded as physiological was achieved in 36–40% of patients, depending on the venous segment taken into consideration. Recently, few reports confirmed this observation. In a retrospective study conducted by Puggioni et al., normalised reflux was obtained in 30–60% of cases following a laser ablation of the great saphenous vein (2). Another study conducted by Ahmad et al. reported decreased reflux times in 83% of patients following an aggressive therapy that included removal of the great saphenous vein, removal of varicose veins and sclerotherapy of spider veins (5). Similarly, Ciostek and MacKenzie obtained a statistically significant decrease in the venous reflux time after the removal of the great saphenous vein (2, 4).

The reduction of the diameter in the deep system veins after surgical procedure also contributes to the improvement in the valves' competence. In a population study including 9261 subjects, Kröger et al. demonstrated that the diameter of veins in the deep and superficial system increased with CEAP classification stage (23). In Ahmad's work, a decrease in vein diameter was observed after a radical treatment of superficial vein incompetence (5). We obtained similar results in our study by demonstrating that the cross-sectional area of the popliteal vein significantly decreased, with values approximating those of the control group. The cross-sectional area of the femoral veins also decreased, but in this case statistical significance was not reached.

Conclusion

Our results demonstrate that the removal of the incompetent great saphenous vein improves the haemodynamic conditions within the operated extremity. In some patients, the reflux in the deep vein system can also be eliminated. The surprising observations of the statistically significant increases in flow quantity in the deep vein and arterial systems contribute to our better understanding of the pathophysiological changes in the chronic venous disease, even if further studies are needed.

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