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The fate of calf perforator veins after saphenous vein laser ablation

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PURPOSE
We aimed to assess hemodynamic changes in calf perforator veins (PVs) after endovenous laser ablation (EVLA) of saphenous veins.

METHODS
The series comprised 60 limbs of 41 patients (27 female, 14 male; median age, 43 years [range, 22–78 years]) who underwent EVLA for varicose veins. All patients were prospectively evaluated by means of color Doppler ultrasonography before and after the procedure.

RESULTS
EVLA did not change the rate of incompetent PVs (preoperatively, 154/483 [32%] vs. postoperatively, 167/501 [33%]; $P = 0.173$), but significantly increased the total number of all PVs (n=483 vs. n=501, $P = 0.036$). Following EVLA, 28% of the limbs had thrombosis of PVs, 34% had new US-detectable PVs, 42% showed new competency, and 52% showed new incompetency. New competent PVs were found more commonly in the medial leg (ablation site) than the lateral leg (nonablation site) (28.3% vs. 11.7%, $P = 0.016$), while new incompetent PVs were found more commonly in nonablation site than ablation site (31.7% vs. 18.3%, $P = 0.086$). Additionally, new competent PVs in the posterior leg were found more often in patients who had small saphenous vein ablation than patients who did not (30% vs. 0%, $P = 0.002$).

CONCLUSION
EVLA induces numerous changes in calf PVs. These changes seem to result from flow offloading in ablation site and onloading in nonablation site in the early postablation period.

Perforator veins (PVs) connect the superficial veins with the deep venous system, and are usually seen in patients with chronic venous disease (CVD). However, the role of PVs in the cause and management of varicose veins and CVD continues to be debated despite significant research and clinical experience (1–3). The prevalence and diameter of PVs correlate well with the severity of CVD. Many previous reports have suggested that incompetent PVs may result in venous hypertension and play an important role in the development of recurrent varicose veins and nonhealing or recurrent venous ulcers after varicose vein surgery (4, 5).

Elimination of superficial reflux has been classically accomplished through surgery. However, thermal ablation methods such as endovenous laser ablation (EVLA) and radiofrequency ablation are gradually becoming the treatment of choice (6, 7). The outcome of venous leg perforators after surgical eradication of superficial reflux has been reported in a few studies. Limited data show that superficial varicose surgery abolishes incompetence in some calf perforators and offer protection against development of new perforator incompetence (8). Ligation and stripping of great saphenous vein (GSV), ligation of small saphenous vein (SSV) with or without phlebectomies eliminate the reflux in 20% to 55% of limbs with preoperative incompetent PVs (8–11). However, to the best of our knowledge, there is no data in the literature about the effect of laser ablation of saphenous veins on leg perforators. The aim of this study was to evaluate the morphologic and hemodynamic changes in the calf perforators after EVLA of saphenous veins and elucidate factors that influence these changes.

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Methods

The series comprised 60 limbs of 41 symptomatic patients who underwent EVLA procedure for saphenous vein insufficiency. Informed consent was obtained from each patient. The study conformed to the reporting standards outlined by joint statement of the American Venous Forum and the Society of Interventional Radiology (12). All patients were prospectively evaluated clinically and by means of color Doppler ultrasonography (CDUS) before and after the EVLA procedure. Patients with a history of deep venous thrombosis (n=2), previous varicose vein surgery or injection sclerotherapy (n=3) and patients who did not return for follow-up evaluations (n=3) were excluded.

Color Doppler ultrasonography

CDUS was performed while patients were standing erect with weight on the contralateral leg. All patients were evaluated with CDUS before the procedure and one to six months after the procedure. The entire proximal deep venous system (common femoral, femoral, and popliteal veins), the great and small saphenous veins, and calf perforators were examined by means of CDUS using 13–5 or 9–4 MHz multifrequency linear array transducers (Antares, Siemens Medical) for the presence of reflux during Valsalva maneuver and/or relaxation phase, while performing calf compression. Reflux with a duration of >500 ms in the saphenous veins and the calf perforators, and >1000 ms in the femoral and popliteal veins were considered pathologic. A calf perforator vein was defined as a vessel that was clearly seen to be crossing the deep fascia. Calf perforators were examined by color-flow and spectral Doppler analysis functions, and all examinations involved a 360° assessment of the calf. The foot and thigh were not assessed in this study. The locations of calf PVs were classified as medial, posterior, or lateral leg. All CDUS examinations before and after treatment were performed by one experienced radiologist. The number of competent and incompetent PVs and measurements of maximal diameters of PVs at the suprafascial and subfascial levels were investigated and recorded before and after the treatment. The presence of new competency in incompetent PVs, new incompetency in competent PVs, partial or total thrombosis of PVs, and new US-detectable PVs were also evaluated after the treatment. This evaluation was performed at each follow-up. The last follow-up examination was used for statistical comparison. For the purpose of the study, the types of PVs were defined as: original, any PV noted before endovenous laser ablation procedure; absent, a PV previously observed but no longer identified after the treatment; thrombosed, a PV noted preoperatively and thrombosed after the treatment; new US-detectable PV, any PV not seen before the procedure; new competency, a PV observed as incompetent previously, but became competent after the procedure; new incompetency, a PV observed as competent previously, but incompetent after the procedure. Definitions of the types of PVs were modified from the study by van Rij et al. (2).

Main points

- Perforator veins are veins connecting the superficial with the deep venous system, usually seen in patients with chronic venous disease. The role of perforator veins in the cause and management of varicose veins and chronic venous disease continues to be debated.
- Perforator veins may result in venous hypertension and play an important role in development of varicose veins and nonhealing or venous ulcers.
- There are no data in the literature about hemodynamic results of laser ablation of saphenous veins on leg perforators.
- Our study shows that EVLA has a profound effect on the calf perforator veins. It seems that these changes result from flow offloading on some perforator veins in ablation sites and flow loading on others in nonablation sites due to redirected venous flow.

EVLA procedure

Potential risks and benefits of EVLA were explained before the procedure, and informed consent was obtained. The leg was prepared in a sterile manner. Under ultrasonography guidance, the GSV was punctured either at the level of the knee or below the knee, whereas SSV was punctured approximately 10 cm proximal to the ankle. All procedures were performed under local anesthesia supplemented with intravenous sedation and analgesia using dormicum and fentanyl citrate. The EVLA procedure was the same for all patients. After successful puncture of the vein with a micropuncture needle (Cook Medical), a 0.018-inch guidewire was inserted into the vein, which was then exchanged with a 0.035-inch standard guidewire through the 4F dilator of the micropuncture set. A 5F long sheath of the laser system was advanced over the guidewire up to the saphenofemoral or saphenopopliteal junction. Then a 600 µm laser fiber (Dornier, MedTech Laser GmbH) was inserted into the sheath, and fixed to the sheath via its valve or a Y connector. We verified that the tip of the laser fiber was located 1–2 cm distal to the saphenofemoral or saphenopopliteal junction with ultrasonography guidance. Next, tumescent anesthesia was applied around the saphenous vein via ultrasound guidance. Normal saline (500–1000 cc) and 2% prilocaine (10–20 cc) were used for tumescent anesthesia. Then, EVLA was performed with continuous laser at 10 W power. Each centimeter of the vein had laser energy for 6–10 s. Our standard procedure consisted of 100 J/cm for proximal part of GSV, 80 J/cm for middle part of GSV and proximal part of SSV, 60 J/cm for distal parts of GSV and SSV. No additional treatment such as sclerotherapy, varicectomy or PV surgery was performed on patients at any point during the study.

After the procedure, patients were given nonsteroidal anti-inflammatory medicine for one to two weeks, depending upon the severity of their complaints. They wore class II (30–40 mmHg) stockings for three to four weeks after the procedure.

Statistical analysis

Sample size calculations were based on detecting a 28% reduction in the total number of limbs with incompetent PVs imaged on CDUS (11). For 80% power and a two-sided significance of 5%, 48 limbs were required in the study population. SPSS statistical software package version 17 (SPSS Inc.), was used to perform all statistical analyses. Comparisons were performed with Mann-Whitney U or Wilcoxon signed ranks tests for continuous variables and with the Pearson chi-square for discrete variables. The number and diameter changes of PVs before and after the treatment were assessed using the Wilcoxon signed ranks test. Clinical variables were assessed for development of new US-detectable perforators, new competency, and new incompetency by using Mann-Whitney U and the Pearson chi-square tests. Significant clinical variables in univariate analysis were selected as risk factors in the multivariate analysis using logistic regression. *P* values less than 0.05 were defined as significant.

Results

The series comprised 60 limbs of 41 patients (27 females [66%], 14 males [34%]; median age, 43 years; range, 22–78 years). The demographic features of the patients are given in Table 1. Only GSV was ablated in 29 limbs (48%), only SSV was ablated in three limbs (5%) and both GSV and SSV were ablated in 28 limbs (47%). When reflux was found in both GSV and SSV, ablations of these veins were performed in the same session. A median energy of 4718 J/limb (range, 2125–6983 J/limb) was delivered for the GSV and 2083.5 J/limb (range, 1019–3150 J/limb) was delivered for the SSV. Initial technical success was obtained in all EVLA procedures. After the procedure, the median venous clinical severity scores improved significantly, falling from a score of 5 (range, 1–21) to 3 (range, 0–12) ($P < 0.001$).

Patients were evaluated with CDUS 1–35 days (median 12 days) before and 3–27 weeks (median 10 weeks) after the procedure. Follow-up CDUS examinations were performed at one month for 11 limbs (18%), three months for 31 limbs (52%), and six months for 18 limbs (30%). All ablated saphenous veins were occluded at the one-month follow-up CDUS. However, CDUS at three or six months revealed partial recanalization of two GSVs and one SSV (5%). The median numbers of incompetent PVs and all PVs per limb were 2 (range, 0–7) and 8 (range, 3–16) preoperatively, whereas they were 3 (range, 0–7) and 8 (range, 3–16) postoperatively. EVLA did not change the proportion of incompetent PVs (preoperatively, 154/483 [32%] vs. postoperatively, 167/501 [33%], $P = 0.173$), but resulted in a significant increase in the total number of all PVs (preoperatively, n=483 vs. postoperatively, n=501; $P = 0.036$). After treatment, the number of PVs was increased in 20 limbs (34%), decreased in 11 limbs (18%) and unchanged in 29 limbs (48%). Seventeen previously observed perforator veins in 11 limbs (18%) became absent after treatment. Absent PVs were not related to any clinical variables. Thirty-five new US-detectable perforators were found in 20 limbs (34%), of which 14 (70%) were in the left limb ($P = 0.035$). Other variables were not related with development of new US-detectable perforator on univariate analysis.

After the procedure, there were 18 partial or complete thrombosis of the PVs in 17 limbs (28%); 34 new competent PVs in 25 limbs (42%), and 48 new incompetent PVs in 31 limbs (52%). All thrombosed PVs were a direct tributary to the ablated saphenous veins. On univariate analysis, new competent PVs were more frequent in left limbs than in right limbs (72% vs. 28%; $P = 0.008$); in patients with SSV ablation than in patients without SSV ablation (58.1% vs. 24.1%; $P = 0.008$); in patients with both saphenous vein ablations than in patients with single saphenous vein ablation (63.3% vs. 20%; $P = 0.001$); in patients with higher number of all PVs detected preoperatively than in patients with lower number of all PVs detected preoperatively (median, 8; range, 3–16 vs. median, 7; range, 4–12; $P = 0.047$) and in patients with higher number of incompetent PVs assessed preoperatively than in patients with lower number of incompetent PVs assessed preoperatively (median, 3; range, 1–7 vs. median, 2; range, 0–6, $P = 0.001$). The left limb (OR=16.69; %95 CI, 2.4–158.4; $P = 0.005$) and higher number of the incompetent PVs assessed preoperatively (OR=3.0; %95 CI, 1.2–7.2; $P = 0.014$) were independent predictors of development of new competent PVs on multivariate analysis. After the treatment, new competency rates were 36% at one month, 48% at three months, and 33% at six months. The time of control CDUS examination was not a significant predictor of new competency ($P = 0.541$).

New incompetent PVs were more frequent in male patients than in female patients (64.3% vs. 29.6%; $P = 0.033$); in patients with shorter follow-up time (≤10 weeks) than in patients with longer follow-up time (>10 weeks) (66.7% vs. 36.7%; $P = 0.020$) and in patients with higher number of incompetent PVs assessed preoperatively than in patients with lower number of incompetent PVs assessed preoperatively (median, 3; range, 0–7 vs. median, 2; range 0–6; $P = 0.034$) on univariate analysis, but none of them were an independent predictor by multivariate analysis. Although the rates of new competency did not differ by CDUS examination throughout the follow-up period, new incompetency was more common in one to three months than in six months. The rates of new incompetency were 54% at one month, 68% at three months and 22% at six months. The time of control CDUS examination was a significant predictor of new incompetency ($P = 0.009$).

The anatomic distributions of new competent and incompetent perforators after the treatment were quite different. New competent PVs arose proportionately more in the medial leg than the lateral leg (28.3% vs. 11.7%, $P = 0.016$), whereas new incom-

Table 1. Demographics and risk factors of study population

Age (years), median (range)	43 (22–78)
Male/female, n (%)	14 (34)/27 (66)
Right/left limb, n (%)	29 (48)/31 (52)
Duration of complaint (years), median (range)	10 (1–50)
CEAP score (1–3), n (%)	44 (73)
CEAP score (4–6), n (%)	16 (27)
Insufficiencies	
GSV, n (%)	57 (95)
SSV, n (%)	31 (52)
Femoral vein, n (%)	25 (42)
Popliteal vein, n (%)	13 (29)
Diameter of GSV (mm), median (range)	6 (3.5–15)
Diameter of SSV (mm), median (range)	3 (2–10.4)
Preoperative median number of IPVs/total PVs (per limb)	2/8
Postoperative median number of IPVs/total PVs (per limb)	3/8
Preoperative total IPVs/total PVs, n (%)	154/483 (32)
Postoperative total IPVs/total PVs, n (%)	167/501 (33)

CEAP, Clinical-Etiologic-Anatomic-Pathologic (classification system for chronic venous disorders); GSV, great saphenous vein; SSV, small saphenous vein; IPVs, incompetent perforator veins; PVs, perforator veins.

Table 2. Median diameters of calf perforators before and after endovenous laser ablation

	Preoperative Median (range)	Postoperative Median (range)	P
Diameter of CPVs at suprafascial level, mm	2.3 (1.6–4.0)	2.2 (1.6–3.9)	0.192
Diameter of CPVs at subfascial level, mm	2.3 (1.5–3.7)	2.3 (1.5–3.6)	0.019
Diameter of IPVs at suprafascial level, mm	3.5 (1.8–5.7)	3.3 (1.6–5.8)	0.010
Diameter of IPVs at subfascial level, mm	3.3 (1.8–6.9)	3.2 (1.6–5.8)	0.003

CPVs, competent perforator veins; IPVs, incompetent perforator veins.

petent PVs were more common in the lateral leg than the medial leg (31.7% vs. 18.3%, $P = 0.086$). Additionally, new competent PVs in the posterior leg were more common in patients who had SSV ablation than patients who did not (30% vs. 0%, $P = 0.002$).

Moreover, EVLA resulted in a small reduction in the suprafascial diameter of competent PVs which was not statistically significant (median, 2.3 mm; range, 1.6–4.0 mm vs. median, 2.2 mm; range, 1.6–3.9 mm; $P =$ 0.192), whereas there was significant reduction in subfascial diameter of competent PVs (median, 2.3 mm; range, 1.5–3.7 vs. median, 2.3 mm; range, 1.5–3.6 mm; $P = 0.019$); in suprafascial diameter of incompetent PVs (median, 3.5 mm; range, 1.8–5.7 vs. median, 3.3 mm; range, 1.6–5.8 mm; $P = 0.010$); and in subfascial diameter of incompetent PVs (median, 3.3 mm; range, 1.8–6.9 mm vs. median, 3.2 mm; range, 1.6–5.8 mm; $P = 0.003$) (Table 2). The difference of PV diameter was stable throughout the follow-up period.

Discussion

This study shows that EVLA has a profound effect on the calf perforator veins. Following EVLA, 28% of the limbs had thrombosis of PVs, 34% had new US-detectable PVs, 42% showed new competency, and 52% showed new incompetency. Competent and incompetent PVs emerged after the procedure so that the proportion of incompetent PVs did not change significantly (32% before EVLA vs. 33% after EVLA, $P =$ 0.173). EVLA resulted in newly developing competent PVs more commonly in medial and posterior leg (ablation sites) than in the lateral leg (nonablation site), and new incompetent PVs more commonly in the lateral leg than in the medial and posterior leg. It seems that venous flow was redirected after saphenous vein ablation, as some lateral leg perforators distant from the ablation site received more flow and became incompetent, whereas medial and posterior leg perforators close to the ablation site received less flow and became competent. New incompetency was suggested to result from progression of venous disease or redirected venous flow after eradication of superficial venous reflux (10). We believe that redirected venous flow played a more important role than the disease progression based upon two findings; first, the increase in the new incompetency was mostly in nonablation sites, and second, the rate of limbs with new incompetency decreased significantly at the six month follow-up compared with the one- and three-month follow-ups. Additionally, after laser ablation of saphenous veins we found 35 new US-detectable PVs and noticed the absence of 17 PVs. Therefore, there was an increase in the total number of PVs (preoperatively, n=483 vs. postoperatively, n=501). One possible explanation is that many small perforators remain undetected by ultrasound because of their size. However, these perforators become detectable as they enlarge and remodel under the influence of changing venous hemodynamics after treatment.

It has been reported that incompetence of PVs is corrected by surgical eradication of superficial reflux in most cases (1, 2, 9, 10). The lack of incompetent PVs in some legs following saphenous stripping or multiple phlebectomies may be attributable to perforator avulsion. Another explanation is that reflux in the superficial venous system may overload the deep veins, resulting in venous dilatation and perforator incompetence. Hence, surgical eradication of superficial venous reflux offloads the deep venous compartment sufficiently to reduce dilatation and reverse perforator incompetence (11). However, saphenous surgery alone failed to correct incompetence of PVs in patients with superficial reflux that persists postoperatively, or when there is coexistent deep venous reflux (11, 13). Statistical evaluation for correction of PV incompetency did not include multivariate analysis in those studies. By contrast, the current study and some previous studies have suggested that presence of deep venous insufficiency did not predict the appearance of incompetent perforators (2, 10). We found that presence of femoral and/or popliteal reflux was not related to correction of incompetence of PVs on multivariate analysis, but left leg and the frequency of incompetent PVs assessed preoperatively were independent predictors of new competency on multivariate analysis. If the number of the incompetent PVs was higher preoperatively, the probability of developing new competency was also higher after treatment. Unfortunately, we could not comment as to why the left leg was an independent predictor of either new competency or new developing US detectable perforator veins. The only known disparity between the left and right leg venous systems is the presence of compression on the left common iliac vein by the overlying right common iliac artery (14, 15). However, it is not known whether this compression, if present, has any impact on the perforating veins or not.

We know from surgical studies that eradication of superficial venous reflux also significantly reduces the median perforator diameter (2, 13). In this study, although the proportion of incompetent PVs did not change and the total number of calf perforators increased, diameters of competent and incompetent PVs were reduced by saphenous vein ablation. Diameter reduction was more prominent in incompetent PVs than competent ones. Flow offload on calf perforators seems to be responsible for this reduction.

Previous studies have demonstrated that both surgical and endovenous ablation of the saphenous veins greatly improve clinical symptoms. However, residual or recurrent varicose veins and clinical symptoms are the major problem after surgery or EVLA (4, 5, 16). The presence of incompetent PVs after ablation of the saphenous vein has been defined as a major risk factor for nonhealing and recurrent leg ulcers in patients with severe CVD (C4–6) and for recurrence of varicosities in patients with mild to moderate CVD (C1–3) (17). Since, it is important to understand the hemodynamics of PVs and hemodynamic changes in PVs after surgery or EVLA, this new area needs further studies.

Our study is limited because we have no data about the midterm and long-term effect of saphenous vein ablation on calf perforators. Most patients had a relatively short follow-up. Long-term follow-up of the perforator veins after saphenous ablation therapy may provide more accurate results. Another important limitation was that we did not assess perforators in other locations such as the thigh, knee, ankle, and foot so calf perforators do not represent all leg perforators. Lastly, we did not evaluate the diameter change of perforator veins in the ablation and nonablation sites separately.

In conclusion, numerous morphologic and hemodynamic changes including new US-detectable PVs, thrombosis of PVs, new competency and new incompetency of perforator veins are seen after laser ablation of the saphenous veins. It seems that these changes result from flow offloading on some PVs in ablation sites and flow loading on others in nonablation sites due to redirected venous flow in the early postablation period.

Conflict of interest disclosure

The author declared no conflicts of interest.

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