Factors Influencing the Effectiveness of Endovenous Laser Ablation (EVLA) in the Treatment of Great Saphenous Vein Reflux

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Objective. Endovenous laser ablation (EVLA) is an alternative to surgery for treating sapheno-femoral and great saphenous vein (GSV) reflux. This study assesses factors that might influence its effectiveness.

Design. Prospective, observational study.

Method. EVLA was used to treat the great saphenous vein in 644 limbs as part of the management of varicose veins. Body mass index (BMI), maximum GSV diameter, length of vein treated, total laser energy (TLE) and energy density (ED: Joules/cm) delivered were recorded prospectively. Data from limbs with ultrasound confirmed GSV occlusion at 3-months were compared with those where the GSV was partially occluded or patent. Complications were recorded prospectively.

Results. GSV occlusion was achieved in 599/644 (93%) limbs (group A). In 45 limbs (group B) the vein was partially occluded (n = 19) or patent (n = 26). Neither BMI [group A: 25.2 (23.0–28.5); group B: 25.1 (24.3–26.2)], nor GSV diameter [A: 7.2 mm (5.6–9.2); B: 6.9 mm (5.5–7.7)] influenced success. TLE and ED were greater \( p < 0.01 \) in group A (median [inter-quartile range]: 1877 J (997–2350), 48 (37–59) J/cm) compared to group B (1191 J (1032–1406), 37 (30–46) J/cm). Although TLE reflects the greater length of GSV ablated in Group A (33 cm v 29 cm, \( p = 0.06 \)) this does not influence ED. GSV occlusion always occurred when ED \( \geq 60 \) J/cm with no increase in complications.

Conclusions. ED (J/cm) of laser delivery is the main determinant of successful GSV ablation following EVLA.

Introduction

Endovenous laser ablation (EVLA) is a relatively new minimally invasive treatment for varicose veins and can be used to abolish reflux from the sapheno-femoral (SFC) or sapheno-popliteal confluence (SPC) and the associated axial vein (great saphenous vein [GSV], small saphenous vein [SSV]). Successful treatment depends upon elimination of the highest point of “deep to superficial” incompetence and ablation of the incompetent axial vein.1–7 EVLA aims to achieve selective ablation of the incompetent GSV and eliminate both GSV and SFC reflux. Previous studies indicate that ablation is achieved in 88–100% of limbs.8

Similar success rates are reported for radiofrequency ablation (RFA)9–12 which causes endothelial denudation, collagen denaturation and acute vein constriction.13 Whilst RFA relies on a standard protocol for the treatment of all patients this is not the case for EVLA. The power of the laser, the total energy delivery and the amount of energy delivered/cm of vein (energy density) are all under the control of the operator although when introduced for clinical use the manufacturer’s original advice was to use 12 watts power to deliver around 48 J/cm vein. Nevertheless few studies report 100% occlusion rates and the factors that might influence this are not fully understood. This observational study analyses those that could influence the effectiveness of EVLA with the aim of establishing a standardised protocol to ensure successful ablation in as many patients as possible.

Methods

Patients

All patients attending the venous clinics of the Leeds General Infirmary and the BUPA Hospital Leeds...
between January 2002—April 2006 with varicose veins due to SFC and GSV reflux were evaluated by duplex ultrasound to assess their suitability for EVLA. A portable duplex ultrasound system (TITAN®, Sonosite Inc, Bothell, USA) with a 5–10 MHz linear probe was used to examine both the superficial and deep venous systems of the symptomatic limbs. Patients were studied whilst standing. Using the colour flow facility the presence of reflux was initially determined following manual calf compression and release. Reflux duration of >1 s on the Doppler trace was considered significant. When appropriate, EVLA was offered as an alternative to surgery and patients were subsequently treated according to their preference. Those who required ablation of an additional axial vein (anterior saphenous vein or SSV) or who were taking warfarin were excluded from the study.

EVLA suitability

Suitability for EVLA depended upon a ≥10 cm relatively straight segment of GSV immediately distal to the SFC, an absence of significant varicosities arising within 10 cm of the SFC, and a GSV diameter of ≥3 mm at the intended cannulation site (usually just above the knee).

Standard laser technique

Under ultrasound guidance the GSV was cannulated at or slightly above the level of knee using a Seldinger technique. A guide wire was passed proximally into the femoral vein and a 5F (1.67 mm) catheter was positioned under ultrasound control 0.5–1 cm distal to the SFC. Perivenuous tumescent local anaesthesia (0.1% lignocaine, 150–200 ml) was infiltrated along the vein under ultrasound guidance. A bare-tipped laser fibre connected to an 810 nm diode laser source was inserted via the catheter and then gradually withdrawn so that 3–5 pulses of laser energy (12 Watts power, 1 second pulses, 1 second intervals) were delivered/cm vein. Neither concomitant phlebectomies nor foam sclerotherapy were used to treat varicosities at the time of EVLA. Following treatment a non-stretch compression bandage was applied to the limb for 1 week followed by a class 2 support stocking for a further week. Patients were prescribed 50 mg diclofenac sodium tds for 3 days to reduce inflammatory ‘phlebitis’ of the GSV. Patients were encouraged to resume their daily activities (including work) as soon as possible.

Follow-up

Patients were reviewed at 6 and 12 weeks. Treated limbs were assessed clinically and by duplex ultrasound scanning. Those who had residual varicosities with controlled axial reflux (occluded treated vein) were offered foam sclerotherapy (sodium tetradecyl sulphate) at the 6 week visit. Patients with persisting significant reflux at any follow-up appointment were offered a choice of either surgery or repeat EVLA.

Criteria for successful GSV ablation on ultrasound were non-compressibility or disappearance of the treated segment of vein together with absence of flow on colour-flow duplex ultrasound and a competent SFC. Treatment failures were defined as veins demonstrating flow and/or reflux in the treated GSV.

Data collection and analysis

Data were collected prospectively by 3 research fellows and 2 consultant vascular surgeons trained in venous duplex ultrasound and recorded on a database. The height and weight of patients (without footwear) was measured on the day of treatment and used to calculate the body mass index (BMI) of each patient. The maximum diameter of the GSV was measured using ultrasound (avoiding focal dilatations) while standing and the length of vein treated (L) calculated by reference to the 45 cm sheath used for laser fibre insertion. The total laser energy (TLE) was directly obtained (Joules) from the laser source after each treatment enabling calculation of the energy density (ED, J/cm). A prospective log of complications occurring after EVLA was also maintained.

Two groups of patients were identified: those with a full-length occlusion of the treated GSV and a competent SFC (Group A) and those who had a patent or partial occlusion of the axial vein, irrespective of their clinical improvement and the reflux status of the SFC (Group B).

Statistical analysis

Variables were compared between the two groups using a student-t test (unpaired) and a chi-square test employed to compare complication rates between the groups. A “p” value of <0.05 was considered statistically significant. Data are presented as median (interquartile range) unless stated otherwise. All analysis were performed by statistical package SPSS® for Windows (SPSS (14), Chicago, Illinois, USA).
Factors Influencing the Effectiveness of EVLA

Table 1. Patient demography and disease severity scores

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number of patients</td>
<td>582</td>
</tr>
<tr>
<td>Median age (range)</td>
<td>50 years (16–86)</td>
</tr>
<tr>
<td>Women</td>
<td>378 (65%)</td>
</tr>
<tr>
<td>Men</td>
<td>204 (35%)</td>
</tr>
<tr>
<td>Number of treated legs</td>
<td>644</td>
</tr>
<tr>
<td>Primary varicose veins</td>
<td>534/644 (83%)</td>
</tr>
<tr>
<td>Recurrent varicose veins</td>
<td>110/644 (17%)</td>
</tr>
<tr>
<td>C2 Varicose veins</td>
<td>361 (56%)</td>
</tr>
<tr>
<td>C3 Oedema</td>
<td>59 (9.2%)</td>
</tr>
<tr>
<td>C1 Skin changes</td>
<td>172 (26.7%)</td>
</tr>
<tr>
<td>C5 healed ulcer</td>
<td>33 (5.1%)</td>
</tr>
<tr>
<td>C6 active ulcer</td>
<td>19 (2.9%)</td>
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CEAP score: Clinical, Etiology, Anatomy, Pathology.

Results

582 patients (644 legs) have been followed-up for a minimum of 3 months. Demographic data, including the severity of the venous disease (CEAP) are shown in Table 1. Group A comprised 599/644 (93%) limbs in which the most recent ultrasound scan confirmed complete ablation of the treated GSV. Of the remainder (Group B) the GSV was partially occluded in 19/644 (3%) legs and patent in 26/644 (4%). The median energy density delivered during ablation was 48 J/cm in Group A and 37 J/cm in Group B. This difference was highly significant (p < 0.01, t-test). These results, and other details about the laser energy administered and data to support the conclusion that BMI, maximum GSV diameter and the length of vein ablated did not influence outcome are summarised in Table 2.

A Hosmer-Lemeshow goodness of fit test confirmed good overall fitness of the model and a logistic regression analysis revealed that energy density is the single most significant (p = 0.001) predictor of the outcome. The ED administered ranged from 22–82 J/cm and this was used to sub-group the treated limbs (Table 3). Regression analysis was performed on the graded ED and the odds ratio (per grade of ED) was 0.49; 95% CI 0.36–0.67; p < 0.001. The frequency of successful ablation was greater with increasing ED and when this was ≥60 J/cm GSV ablation was achieved in all limbs (100%). Importantly, a higher ED did not appear to increase the rate of complications. In particular the frequency of symptomatic ‘phlebitis’ in veins that received ≥60 J/cm or <60 J/cm was 8% (7/86) and 11% (59/549) respectively (p = 0.316).

In group A, 391 (65%) limbs were clinical class C2–3 and 208 (36%) were C4–6. Similarly in group B, 31 (69%) limbs were C2–3 and 14 (31%) limbs were C4–6. A Chi square test showed that the clinical severity was similar in both groups (p = 0.376) and did not predict success or failure.

Discussion

The findings of this study form the basis for developing a standardised protocol for successful EVLA. It is clear that an ED of energy density ≥60 J/cm is central to achieving complete GSV occlusion. This equates to 5 pulses/cm vein when using 12 watts power, 1 second pulses and 1 second intervals for laser fibre withdrawal i.e. 2 mm pull-back during each 1 s interval. The choice of pulsed laser for EVLA was based on the description of the technique and the results reported by Min et al. in 2001. Continuous withdrawal of the fibre using 14 watts power has also been advocated (Min RJ, personal communication) although it had not been suggested when patients were first recruited to this database in 2002. This method has now been adopted in our unit following confirmation, in an unpublished prospective audit, that initial concerns about both the efficacy of ablation (more rapid withdrawal) and a possible increased risk of post-treatment “phlebitis” or skin burns (higher power) were unfounded. The principle benefit of continuous withdrawal is a reduction in treatment time although there is no evidence in the literature to suggest that one technique is more effective than the other.

Delivery of 60 J/cm with continuous withdrawal requires a pull-back rate of 1 cm of the laser fibre in 4.3 s. For practical purposes we have adopted a policy of withdrawing 1 cm of fibre in 5 s equating to the delivery of 70 J/cm. Again we have found no evidence of a higher complication rate when laser energy is delivered in this way.

Other authors have also assessed the efficacy energy delivery of different densities. Timperman reported similar data to those presented here, with a significant difference in laser energy delivery between “successes” and “failures” (63.4 J/cm versus 46.6 J/cm, p < 0.0001). In this study there were no treatment failures with a laser dose of >80 J/cm although in a subsequent study the same author treated 100 GSV with 95 J/cm achieving successful ablation in 95% of limbs. In contrast Kim et al. achieved 100% technical success in 34 patients using a 980 nm diode laser at 11 W power, delivering 35.16 J/cm. It is likely that a small study such as this reflects either reporting bias or the less secure nature of such data rather than a real finding.

Finally Proebstle et al. have produced data to suggest that the energy delivery required to achieve reliable GSV ablation and low recanalisation rates is dependent not only on the quantity of energy delivered but also on vein diameter. These workers concluded that 6.3 J/cm of energy were required for each mm GSV diameter for effective ablation. Thus,
for a 10 mm diameter vein this equates to 63 J/cm, which is similar to the findings reported here.\textsuperscript{18} Since this data was derived in from patients treated with laser powers of 15 W or 30 W they are not necessarily applicable to the more widely used technique employing 12–14 W power.

The same group have suggested that reporting energy delivery as J/cm is an oversimplification since it does not take vein diameter into account. Thus Proebstle found that laser fluence (laser energy per cm\textsuperscript{2} vein) was a risk factor for non-occlusion\textsuperscript{19} and that treatment regimes should be based upon this type of calculation. Such an argument may be flawed since vein diameter at the time of ablation is significantly reduced due to catheter-induced spasm following cannulation together with the effect of the tumescent anaesthesia. Further, the vein may not be of a uniform diameter throughout its length making the calculation more difficult. The results of the present study suggest that a protocol based on J/cm should be reliable and easier to implement.

Although a protocol delivering $\geq 60$ J/cm would be straightforward it should be used with caution if the vein for ablation is particularly superficial (within $<1$ cm of skin surface). When this is the case care should be taken to ensure that sufficient tumescent anaesthesia is infiltrated between the vein and the skin to prevent skin burns.

Although concern has also been voiced about the risk of nerve injury in the popliteal fossa during EVLA a previous study from our unit has confirmed that provided adequate volumes of tumescent anaesthesia are used the temperature 3 mm from the vein does not reach the temperature (45 °C) at which nerve injury may occur when the energy density is $\leq 60$ J/cm.\textsuperscript{20} Furthermore the clinical results of SSV ablation confirm that it can be performed safely at this level of energy delivery.\textsuperscript{21}

This study has also shown that neither vein diameter nor the length of vein ablated had any influence upon success rates and these findings are not particularly surprising. The impact of BMI upon outcome was also examined since the efficacy of post-EVLA compression might have been reduced in obese patients. Although this did not seem to be an important factor conflicting data have been reported by Timperman\textsuperscript{14} who found a statistically significant difference in body mass index (BMI) between successes and failures (30 versus 46, $p = 0.0009$). This difference might be explained by absence of significant numbers of super-obese patients in our study.

Laser induces thermal injury to venous endothelium and sub-endothelial collagen leading to fibrous sclerosis of the vein.\textsuperscript{22–24} Although different wave length diode lasers (808–1320 nm) have been used for GSV ablation\textsuperscript{15,23–25} this study employed an 810 nm diode laser which proved to be safe, and effective, provided sufficient energy was used.

Successful EVLA depends upon inflicting sufficient vein wall damage to cause contraction and subsequent fibrosis of the treated vein rather than thrombosis which could lead to recanalisation and treatment failure. In order to achieve this, factors other than the quantum of thermal energy delivered to the vein are likely to be important. Generous volumes of tumescent anaesthesia and treatment in the Trendelenburg position should ensure that the vein is empty and that the laser fibre is in close proximity to the vein wall. This should increase the extent of irreversible damage to the vein wall. Further, it ensures that the distribution of energy is more predictable and not dependent upon vein diameter or the volume of blood within the vein at the time of treatment.

<table>
<thead>
<tr>
<th>Table 2. Variables and values for each group (IQR — inter-quartile range)</th>
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<tr>
<td>Variables</td>
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<tr>
<td>Total laser energy (J)</td>
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<tr>
<td>Energy Density (J/cm)</td>
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<tr>
<td>Diameter of the vein* (mm)</td>
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<tr>
<td>BMI (Kg/m\textsuperscript{2})</td>
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<tr>
<td>Length of treated vein (cm)</td>
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Group A: limbs with complete occlusion of the treated GSV.
Group B: limbs with either a patent or partially occluded GSV.
*Maximum diameter measured whilst standing.

<table>
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<tr>
<th>Table 3. Success of GSV occlusion and complications rate according to range of energy density delivered</th>
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<tbody>
<tr>
<td>Energy density (J/cm)</td>
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</tr>
<tr>
<td>&lt;30</td>
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<tr>
<td>30–39.9</td>
</tr>
<tr>
<td>40–49.9</td>
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<tr>
<td>50–59.9</td>
</tr>
<tr>
<td>60–69.9</td>
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<tr>
<td>$\geq 70$</td>
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<tr>
<td>Total</td>
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In conclusion this study has shown that the ED (J/cm) of laser delivery is the main determinant of successful GSV ablation with EVLA and delivery of ≥60 J/cm (810 nm diode laser (pulsed) at 12 W power) is required for optimum results. Neither GSV diameter nor BMI appeared to influence outcome. Finally, the frequency with which phlebitis occurred did not appear to be influenced by the energy density within the study range.

References

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