The evolution of laser technologies for endovenous treatment

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Disclosure

I have the following potential conflicts of interest to report:

(last 12 months)

- [x] Consulting: Covidien, Syneron Candela/Cooltouch, Sapheon
- [ ] Employment in industry
- [x] Stockholder of a healthcare company: Sapheon
- [ ] Owner of a healthcare company
- [ ] Other(s)

- [ ] I do not have any potential conflict of interest
Evolution of Endovenous Laser

- Indications
- Wavelength
- Fiber-Tip Design
- Energy dosing
- Costs of Disposables and Devices
Evolution of Indications for Endovenous Laser

<table>
<thead>
<tr>
<th>Category</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAPHENOUS</td>
<td>GSV, SSV, AASV, APSV</td>
</tr>
<tr>
<td>PERFORATORS</td>
<td>THIGH, POPLITEAL, CALF</td>
</tr>
<tr>
<td>TRIBUTARIES</td>
<td>SUPERFICIAL VARICOSITIES</td>
</tr>
<tr>
<td>RECURRENCE</td>
<td>STUMP, TUBULAR REMNANTS</td>
</tr>
<tr>
<td>MALFORMATION</td>
<td>MARGINAL VEINS, TUBULAR PARTS</td>
</tr>
<tr>
<td>COSMETIC</td>
<td>HAND, ARM VEINS</td>
</tr>
</tbody>
</table>
Indications for Endothermal Tx

Endovenous Radiofrequency Thermal Ablation and Ultrasound-Guided Foam Sclerotherapy in Treatment of Klippel-Trenaunay Syndrome

Nuttawut Sermsathanasawadi, MD, PhD, Kiattisak Hongku, MD, Chumpol Wongwanit, MD, Chanean Ruangsetakit, MD, Khamin Chinsakchai, MD, and Pramook Mutirangura, MD
Indications for Endthermal Tx

_Intravenous catheter-guided laser ablation: a novel alternative for branch varicose veins._

Laser (n=89) superior compared to mini-phlebectomy (n =81)

[comparison to foam sclerotherapy is missing]
Endovenous Laser of Arm Veins (1320 nm Nd:YAG)

Before

After
Evolution of Laser Ablation: Wavelength

- 810, 940, 980 nm diode lasers
- 1064, 1320 nm Nd:YAG lasers
- 1470 nm diode laser
- Not yet established:
  - 1310 nm diode, 1927 Thulium and 2100 nm Holmium
Optical Properties of Circulating Human Blood in the Wavelength Range 400–2500 nm

André Roggan, Moritz Fricke, Klaus Dörschel, Andreas Hahn, and Gerhard Müller

Institut für Medizinische/Technische Physik und Lasermedizin, Universitätsklinikum Benjamin Franklin, Freie Technologie gGmbH

(Paper CDB-007 received

![Graph showing absorption vs. wavelength][1]
Influence of **Wavelength** and **Fiber Tip** on short term Clinical Result and Side effects

Table 3. Comparison of age, pain scores, and energy density (J/cm) in Groups 1 and 2

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (n=54)</th>
<th>Group 2 (n=36)</th>
<th>$p$a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>42.03±11.81</td>
<td>44.21±12.44</td>
<td>0.445</td>
</tr>
<tr>
<td>Pain score</td>
<td>3.25±2.42</td>
<td>3.45±2.30</td>
<td>0.717</td>
</tr>
<tr>
<td>Energy density (J/cm)</td>
<td>101.82±15.63</td>
<td>52.39±7.02</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*a*Student test for equality of variances.

**no difference**

Group 1, 980 nm, 14W, bare fiber, 100% occlusion
Group 2, 1470 nm, 10W, covered tip, 100% occlusion

Collagen Shrinkage and Carbonization properties of a 940 nm diode laser compared to a 1320 nm Nd:YAG laser
Vein Wall Perforation
940 diode vs 1320 nm YAG

Linear Endovenous Energy Density
940 nm: 15 W, 3 mm/s : 45 J/cm
        30 W, 3 mm/s : 100 J/cm
1320 nm: 8 W, 1 mm/s : 80 J/cm
        5 W, 0.5 mm/s: 100 J/cm

1320 nm: no perforation
940 nm: perforation, carbonization

1320 nm 8 W, 1 mm/s control 5 W, 0.5 mm/s control

control 15 W 30 W
20 mm 13 mm 8 mm

940 nm
Evolution of Laser Ablation: Fiber Tips

- Ceramics
- Bare fiber tip
- Tulip
- Metal
- Radial
- Saph-Fire
cylindrical surface area \( A = 2 \pi r \times h \)

surface of the CLF coil:

\[
A = 0.23 \text{ cm} \times \pi \times 7 \text{ cm} = 5.06 \text{ cm}^2
\]

estim. surface of the laser emitting part of the radial fiber tip:

\[
A = 0.12 \text{ cm} \times \pi \times 0.2 \text{ cm} = 0.075 \text{ cm}^2
\]

surface of the laser emitting section of the bare fiber tip \( A = \pi r^2 \)

\[
A = (0.03 \text{ cm})^2 \times \pi = 0.0028 \text{ cm}^2
\]
Energy Flux aprox. 70 J/cm (in 20 s)
→
$I'' = (70 J / 20 s) / (5.06 / 7) cm^2$
$= 0.005 kW/cm^2$

Surface of the CLF coil:

$A = 0.23 \text{ cm} \times \pi \times 7 \text{ cm} = 5.06 \text{ cm}^2$

Estimated surface of the laser emitting part of the radial fiber tip:

$A = 0.12 \text{ cm} \times \pi \times 0.2 \text{ cm} = 0.075 \text{ cm}^2$

Irradiance (10W)
$I = 0.75 \text{ kW/cm}^2$

Surface of the laser emitting section of the bare fiber tip $A = \pi r^2$

$A = (0.03 \text{ cm})^2 \times \pi = 0.0028 \text{ cm}^2$

Irradiance (10W)
$I = 2.8 \text{ kW/cm}^2$
Influence of Wavelength and Fiber Tip on short term Clinical Result and Side effects

Prospective Cohort Study N=312 limbs, 1470 nm Laser Group 1, 1470 nm bare fiber, n=168 limbs Group 2, 1470 nm, radial fiber, n=144 limbs

Less pain, less analgesics in group 2 (p<0.04) 103 +/- 15 mg diclofenac vs 82 +/- 19 mg (single dose is 50 mg) Less bruising in group 2 (p<0.0001)

Evolution of Endovenous Laser ENERGY DOSING

LEED (Linear Endovenous Energy Density) : [Joule/cm]

Energy = power x time  [Joule = Watt x sec]

Example for continuous fiber pullback:

Laser power 10 Watt, pullback 2 mm/sec :

10 Watt x 5 sec/cm = 50 Joule / cm

1 cm vein

laser fiber
**Endovenous Fluence Equivalent**

**Energy deposit per inner vein wall surface [Joule/cm²]**

Cylindrical approximation of the vein wall surface:

Example: LEED = 50 Joule/cm, vein diameter = 2\( r = 6.4 \text{ mm} \)

cylindrical surface: height 1 cm x circumference 2\( \pi r = \)

1 cm x \( \pi 6.4 \text{ mm} = 1 \text{ cm} \times 2 \text{ cm} = 2 \text{ cm}^2 \) -> EFE = 25 Joule/cm²

\[ \text{Circumference} = 2 \pi r \]

\[ \text{1 cm vein} \quad \text{laser fiber} \]
## Importance of Energy Dosing

Laser energy and recanalization, 15 W cont., 940 nm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median [Q1-Q3]</th>
<th>univariate P (Wilcoxon)</th>
<th>logistic regression p (Wald)</th>
<th>Odds ratio (OR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser fluence [Joule / cm²]</td>
<td>closed: 13.2 [9.8 – 15.9]</td>
<td>p &lt; 0.001</td>
<td>p = 0.004</td>
<td>OR = 0.40</td>
</tr>
<tr>
<td></td>
<td>open: 7.2 [5.9 – 8.4]</td>
<td></td>
<td></td>
<td>CI = [0.25 – 0.52]</td>
</tr>
<tr>
<td>Energy per vein length [Joule / cm]</td>
<td>closed: 23.8 [20.1 – 27.2]</td>
<td>p = 0.004</td>
<td>p = 0.572</td>
<td>OR = 0.72</td>
</tr>
<tr>
<td></td>
<td>open: 19.3 [15.9 – 23.5]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance thrombus to SFJ at day 1 after ELT [cm]</td>
<td>closed: 1.1 [0.5 – 1.3]</td>
<td>p = 0.004</td>
<td>p =0.618</td>
<td>OR = 0.78</td>
</tr>
<tr>
<td></td>
<td>open: 2.5 [1.8 – 3.4]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>proximal vein diameter [cm]</td>
<td>closed: 0.64 [0.47 – 0.74]</td>
<td>p = 0.002</td>
<td>p =0.260</td>
<td>OR = 0.28</td>
</tr>
<tr>
<td></td>
<td>open: 0.90 [0.72 – 1.01]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total laser time [sec]</td>
<td>closed: 91.0 [71.0 - 113]</td>
<td>p = 0.046</td>
<td>p = 0.966</td>
<td>OR = 0.99</td>
</tr>
<tr>
<td></td>
<td>open: 72.3 [48.0 – 98]</td>
<td></td>
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</tbody>
</table>

SFJ = saphenofemoral junction, CI = 95%-confidence interval


Recanalization events with respect to the administered EFE.
Evolution of Costs of Disposables 2015

Bare fiber : 80,- €
Radial Fiber : 120,- €
Conclusion

Endovenous LASER Evolution

• Many new Indications
• All wavelengths and all type of fibers work
• Sophisticated fiber tips may save a few doses of NSAIDs
• Energy Dosing stays most important factor for successful ablation
• Economical aspects of devices and disposables will turn dominant
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