PEAK POWER EFFECT ON SKIN REJUVENATION USING IPL: LUMECCA IPL EVALUATION

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Introduction

Intense pulsed light (IPL) technology has become a common tool in medical aesthetic practices for skin rejuvenation. The popularity of IPL technology has increased because of its simplicity, low cost and versatility, allowing for treatment of a variety of vascular and pigmented lesions. The broad spectrum of IPL covers the visible and near infrared spectrum and can be easily adjusted for specific applications by using filters and optimizing lamp parameters. The spectrum of IPL may be used for treatment of pigmented lesions with different levels of aggression; it includes multiple peaks of hemoglobin absorption, and penetrates into the skin down to a few millimeters at longer wavelengths.

The other advantage of IPL is the variability of the pulse width in a relatively broad range from a few milliseconds up to a few hundred milliseconds. Energy can be delivered in a single pulse or in a train of pulses.

Even the first IPL had multiple filters and a sophisticated pulse structure [1]. Future efforts were directed to the optimization of broad spectrum filtering, trying to reach the efficiency of pulse dye laser for treatment of superficial vascular lesions [2]. The treatment results were comparable but at significantly higher fluences than with PDL. These results can be interpreted in two ways: The IPL, even after optimization, has less treatment selectivity, or peak power of the IPL is lower than one of the laser.

The treatment of vascular and pigmented lesions is based on principles of selective photothermolysis suggested by Anderson and Parish [3]:

- Light penetration depth should be high enough to reach the treatment target.
- Light absorption by the treatment target should be higher than by surrounding tissue
- Light should be delivered in pulse manner and pulse duration should be shorter than thermal relaxation time of the treatment target

The authors of [4] tried to demonstrate that long pulse durations of up to 400ms can be as effective as a short pulse, but this concept has proven relevant only in particular scenarios where the “heater” and “real” targets are dimensionally optimized for “very” long pulsed applications. On the contrary, the home use IPLs with sub-millisecond pulses demonstrate reasonable efficiency with fluences less than 4 J/cm^2. [5]

Higher peak powers allow for the following potential treatment benefits:

1. Coagulation temperature in the target can be reached at a lower fluence.
2. Higher selectivity.
3. Smaller targets can be treated.

This article is intended to demonstrate efficiency of the IPL device which is designed to provide the highest peak power and shorter pulse duration for treatment of vascular and pigmented lesions.

Theoretical consideration

Pulse width and its relation with target- specific thermal relaxation times (TRT) is one of the critical elements of selective photothermolysis [6].

$$TRT = \frac{d^2}{A\,\alpha}$$

Where d is size of the treated target, A geometrical factor (A=16 for cylindrical target and A=4 for planar target), α is diffusivity of tissue and can be estimated as one of water (α~10^{-7} m^2/sec).

If pulse width is longer than TRT of the target, a significant part of the energy is dissipated from the target to the surrounding tissue. Figure 1 shows temperature distribution for the pulse with duration of 0.3 of TRT and three times longer than TRT.

One can see that at the same applied energy, the peak target T can be 2X that associated with the longer pulse. Consequently half of the energy is sufficient to reach the T for coagulation.

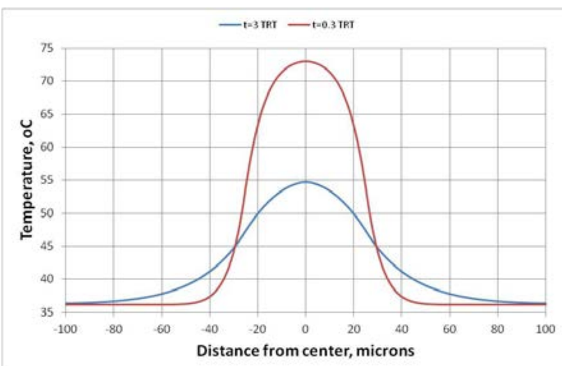

Figure 1. Temperature of 50micron cylindrical object heated with pulse with width of tree times longer than TRT and 3 times shorter of TRT.

In order to destroy single melanosomes, the nano- or pico-second pulse durations are optimal, whereas IPL and other ms devices are more likely to heat the entire dermal-epidermal junction layer. Shorter pulses increase selectivity such that even so called "low contrast" lesions can be treated. Shorter pulses also allow treatment of "early-stage" less pigmented lesions, at times even when they are not visible by the naked eye. Longer pulse injuries are less selective and more discretion must be used by the operator to avoid higher risk of side effects.

The relative number of blood vessels in a body is strongly related to their size. One study [7] analyzed dimensions of blood vessels in a bat's wing and showed that the number of venules exceeds the number of small veins by fifteen times and the number of post-capillary venules is five times higher than number of venules.

Authors of another study [8] measured a number of perfused vessels in human skin. They ranged of 5-12 µm on the lower end (for capillaries) and then up to 250 µm vessels. Measurements were performed using intravital microscopy. Results of measurements are shown in Figure 2.

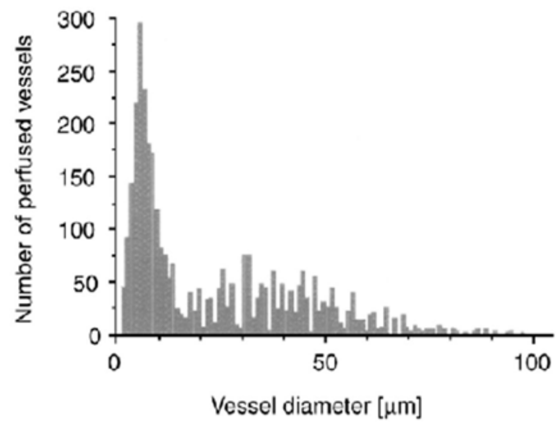

Figure 2. Number of perfused blood vessels versus vessel diameter [8].

This data demonstrated that the ability to treat smaller vessels, presumably with shorter pulses, exponentially increases the number of vessels that can be targeted by a device.

The Figure 3 shows correlation of blood vessel TRT with vessel diameter.

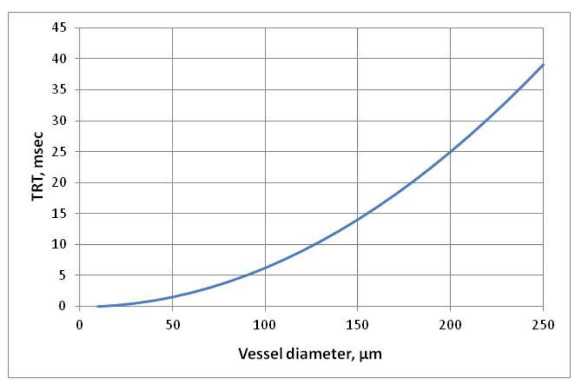

Figure 3. TRT versus vessel diameter.

We can see that for treatment of vessels smaller than 100 µm the pulse should be shorter than 7msec.

Figure 4. Before (left) and after (right) single Lumecca 515 nm treatment, 10 J/cm^2.

Figure 5. Before (left) and immediately after (right) single Lumecca 515 nm treatment, 14 J/cm^2.

Methods and materials

The Lumecca IPL device (InMode Ltd.) was used in a pilot study for treatment of vascular and pigmented lesions. The Lumecca IPL device has a peak power of 3.3 kW/cm^2 and 3 cm^2 area. That combination allows for a fluence of 10 J/cm^2 at a pulse duration of only 3 ms. Such pulse durations correspond to the TRT for vessels with diameters of 70 µm. For comparison, a pulse width of 20 msec corresponds to a TRT of a vessel with diameter of 18 µm. In patients a single treatment with fluence of 8-16 J/cm^2 and filter of 515nm was performed and followed-up after four weeks.

Results and discussion

All patients demonstrated significant improvement of skin discoloration related to vascular and pigmented lesions. The treatment pigment results were achieved with fluences as low as 8 J/cm^2. Typical responses for pigmentation with Lumecca treatment are shown in Figure 4.

Sometimes the Lumecca treatment is accompanied by the same minor purpura that is observed typically with the pulsed dye laser at such a low fluence level. That finding indicates a similar level of selectivity for vascular lesions.

To avoid purpura, the Lumecca 580 nm has been used to reduce aggressiveness of a treatment, or the longer pulsed mode can be applied with the 515 nm handpiece

For larger vessels with the 515 nm filtered handpiece, higher fluences of 12-14J/cm^2 were used in combination with stronger skin cooling (Figure 5). The ability of the device to provide vessel closure at such low fluences can be explained by two reasons:

1. The peak power of the Lumecca is higher than for most other IPLs;
2. High peak power introduced into the lamp during the pulse results in a spectrum shift to the shorter wavelengths and increase of optical energy in the range of 500-600nm where absorption of the melanin and hemoglobin is maximal.

Conclusion

Single treatment with Lumecca provides significant improvement for majority of patients. Exceptionally short pulses provide improvement even for some patients who had previous treatments with other IPL devices. The high peak power of Lumecca makes its effect on vascular lesions comparable to a pulse dye laser.

References

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