A practical comparison of IPLs and the Copper Bromide Laser for photorejuvenation, acne and the treatment of vascular & pigmented lesions.

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Abstract: The recent rapid growth in demand for non-invasive light-based cosmetic treatments such as removal of unwanted facial and body hair, skin rejuvenation, removal of age-related and sun induced blemishes including pigment and vascular lesions as well as lines and wrinkles has led to a boom in the sale of medical devices that claim to treat these conditions. The often onerous safety regulations governing the sale and use of Class 4 lasers has contributed disproportionately to the popularity of similarly powerful non-laser Intense Pulse Light sources ("IPL"), particularly in the salon and spa sector. The practical science-based comparisons made in this review and the well-documented case studies in peer reviewed literature show that single treatment success in eradicating vascular and pigmented lesions may only be achieved by high fluence, wavelength-specific laser treatment and without the need for skin cooling.

Introduction: hair removal with IPL

The recent success of IPL in delaying hair re-growth ("hair management") and permanent hair reduction ("photo-waxing") is dependant upon using high energy settings for the former and is thought to work primarily because melanin absorbs energy across a wide spectrum of wavelengths. Cumulatively enough energy is absorbed to damage the hair follicle. It is also suggested that the longer wavelengths absorbed by blood and tissue water may also collectively damage hair follicle support structures such as the blood supply to the hair bulb aided by the overall temperature rise in the adjacent tissue. The large spot sizes used together with the wide range of wavelengths may also go some way to increase depth of light penetration into the underlying follicular bulb.

Photorejuvenation

This paper is an evaluation, based upon the science, of the differences, advantages and disadvantages of broadband large area light sources such as IPLs compared with narrow band medical laser devices. A Copper Bromide (CuBr) Laser used in photorejuvenation and the treatment of vascular and pigmented blemishes is an example of these devices. The clinical effectiveness of copper lasers producing 511 and 578nm wavelengths is well documented in the literature. [1-54] Dye lasers operating in the narrow range of 580-585nm have similarly shown effectiveness in treating vascular lesions.

Whilst it is generally recognized that new high-powered IPL devices have been shown to be effective in permanent hair reduction, there is little objective evidence of successful treatment of vascular and pigmented lesions let alone stimulation of sufficient collagen neogenesis to improve lines and wrinkles. Some limited cosmetic benefit achieved by reduction in epidermal pigment in photo-damaged skin has been reported using IPLs but only after multiple treatments. (55-57)

The ability to treat large areas in a single pulse and with a system capable of targeting multiple chromophores is seen by some as a distinct advantage compared with narrow beam, small spot size devices such as the CuBr Laser. However, a closer understanding of the comparative advantages of each system is needed before making an informed decision.

It is well documented in numerous published clinical studies, that IPLs require multiple treatments to demonstrate a clinical effect on superficial pigmented and vascular lesions whereas the CuBr laser usually requires only one.

Selective Photothermolysis:

R. Anderson et al. proposed the concept of **photothermolysis** and selective chromophore excitation[58] as the mechanism for vascular and pigmented lesion treatment and reduction. This concept plays a vital role when explaining the difference between treatment using IPL and the CuBr laser. So what are these chromophores and where are they located?

The major relevant skin chromophores are;

Melanin: the pigment generated by epidermal melanocytes (also found in hair).

Haem: the red pigment in blood and other tissue.

Keratin: the desiccated protein that comprises the outer skin layers and hair. It also comprises the warty bulk of keratoses and calluses.

Porphyrins: Naturally occurring protoporphyrinIX (PPIX) can act as photosensitive toxin under certain conditions.

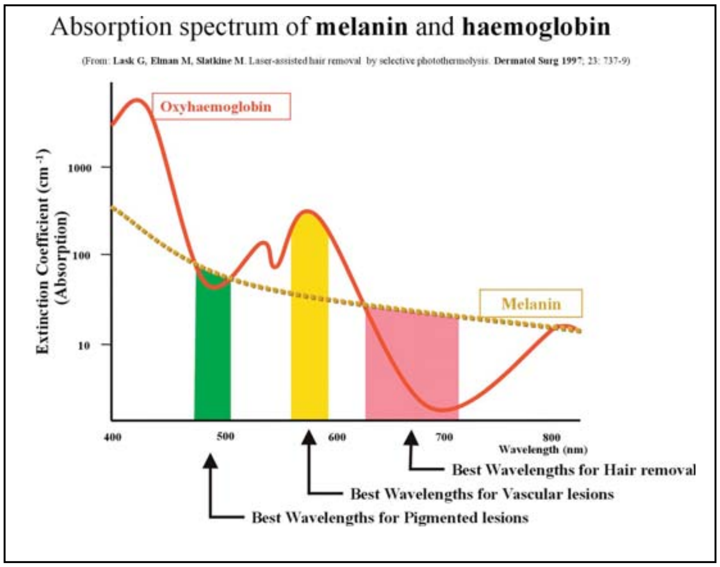
What are the ideal wavelengths for absorption into these chromophores?

Melanin lying over other chromophores can be targeted by a range of wavelengths but because absorption in melanin increases as the wavelength shortens it is better to use green wavelengths e.g. lentigines are easily removed in a single treatment using CuBr laser at 511nm.

Haemoglobin on the other hand has a more distinctive absorption characteristic and has an absorption peak at about 578nm while the absorption in melanin at this wavelength is lower than at the shorter wavelengths thus reducing the level of damage done to melanin-containing structures. Using this specific wavelength when targeting haemoglobin has the advantage of most of the light being able to pass through the melanin but be strongly absorbed by the haemoglobin chromophore. The process of **photothermolysis** then causes dilated capillaries to be selectively coagulated in a single treatment using the CuBr laser operating at the wavelength of 578nm.

Removal of raised keratinous lesions (like seborrhoeic keratosis) using light energy can only be achieved by non-contact photo-coagulation / photo-ablation through efficient absorption in all tissue components. This is a high-energy process and using the CuBr laser it is performed at the high settings. As will be explained shortly these high power requirements are not possible with IPL devices.

Photo Dynamic Therapy (PDT) is the excitation of ProtoPorphyrinIX (PPIX) which has absorption peaks at 508, 542, 577 and 635nm as well as a large peak at about 400nm. Two of the peaks correspond to the spectral output of the Copper Bromide lasers and show great potential for treatments ranging from active acne, skin rejuvenation and Rosacea. It has been reported that large amounts of endogenous porphyrins (PPIX) are produced by P. acnes, by exciting PPIX with the Copper Bromide laser a singlet oxygen radical is produced which destroys the P. acnes [59], implicated in acne vulgaris.



This graph shows the extinction coefficients (absorption) of the two main chromophores, melanin and haemoglobin. It can be seen easily that different wavelengths are required to target the two main chromophores efficiently.

The Factors determining the effectiveness of CuBr vs. IPL treatment.

In contrast to monochromatic laser sources, IPLs provide an intense broadband output which generally covers both the melanin absorption area (green) and the haemoglobin absorption area (yellow) but it also extends into the red region which provides deeper penetration into tissue. By definition, the interaction of these multiple wavelengths with the skin must be non-selective. The CuBr laser on the other hand can selectively provide green at 511nm to treat superficial pigmented lesions, or yellow at 578nm, which almost exactly corresponds with the absorption peak of haemoglobin. The CuBr laser does not provide wavelengths for deeper penetration, i.e. red or infrared (IR). At first glance then, it can be seen that either system should be capable of targeting both the melanin and haemoglobin chromophore, albeit not selectively for IPL. Hence it is relevant to compare the way in which the energy emitted by each device is distributed through the spectrum of interest.

The final temperature to which a chromophore is heated is a function of the rate at which a target chromophore is heated and the heating time (pulse duration). The rate of heating target tissue is measured in W/cm^2 absorbed.

Flash-lamps in IPLs produce a continuous output spectra, which is maximal at the blue end of the spectrum although this is usually filtered out to leave the green region as the maximum intensity. The output falls towards the red region

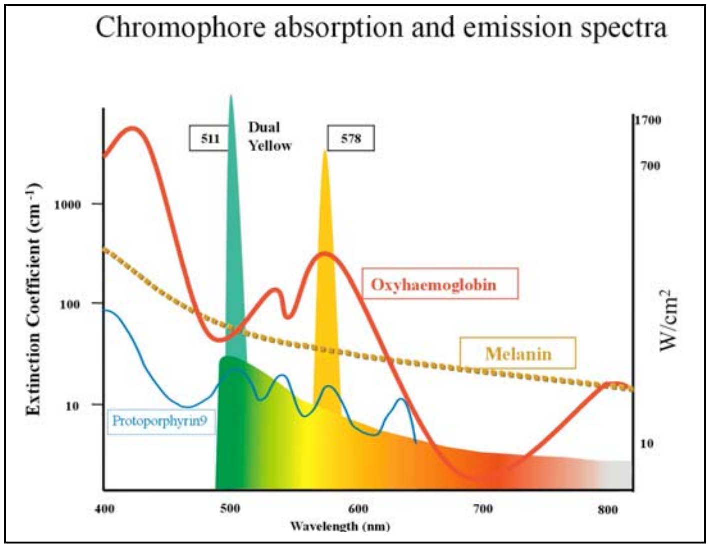
and is usually limited to about 1000nm. Typically, the broad band IPL covers the region from about 400nm in the blue region through to the near IR (1100nm). This light output is usually filtered so that the light is restricted to a limited part of the spectrum (band-pass limited) to the region 500 (green) to 1100nm (approximately).
Some systems also have an optional filter to limit shorter wavelengths, i.e. the green wavelengths, when used to target hair and vascular elements differentially.
It must be emphasized that filters only ***remove*** *unwanted radiation, thus reducing the available total power without any additional benefits at the desired wavelength.*
For a 50J/cm^2 IPL covering the band from 500nm to 1000nm and knowing the spectral output of the IPL, it is possible to calculate the power density in each segment of the spectrum of interest. For example the power density absorbed in the melanin and haemoglobin regions are found by the integrals:

For pigmented treatments:
Power density $Ab_{Melanin}$ (Wcm^{-2}) $\propto P_i \int_{\lambda=530nm}^{\lambda=500nm} P(\lambda) f_{Melanin}(\lambda) d\lambda$

Where P_i is the incident power, $P(\lambda)$ is the spectral distribution of power and $f_{Melanin}(\lambda)$ is the absorption coefficient of Melanin.

For Vascular treatments:
Power density $Ab_{Haemoglobin}$ (Wcm^{-2}) $\propto P_i \int_{\lambda=580nm}^{\lambda=550nm} P(\lambda) \left[(1 - f_{Melanin}(\lambda)) f_{Haemoglobin}(\lambda) \right] d\lambda$
Where $(1 - f_{Melanin}(\lambda))$ is a function of the Melanin transmission and $f_{Haemoglobin}(\lambda)$. the Haemoglobin absorption.
The incident power P_i can be estimated from the output fluence together with the pulse time and train.
For a typical 50J/cm^2 **IPL** the energy in the green region (490nm to 510nm) is about 3.75J/cm^2 and assuming a pulse duration of about 40ms yields a power density of approximately **104 W/cm^2**. For the region 560nm to 580nm the energy density is about 3.4 J/cm^2 giving **96W/cm^2** for this region.

The **CuBr** laser emits only at the desired wavelengths –
511nm (green) with a power density of about **1768W/cm^2** which gives about 53J/cm^2 for a typical 30millisecond treatment pulse.
For the 578nm (Yellow) the power density is about **707W/cm^2** which gives about 17J/cm^2 for a typical 25millisecond treatment pulse.



This graph shows the absorption characteristics of Melanin, Haemoglobin and Porphyrin with the CuBr laser and the IPL wavelengths and relative power overlaid. Note that the Porphyrin curve has peaks corresponding to the two Copper Bromide wavelengths.

Because the IPL energy is spread over a large band width the power at the required wavelengths is low compared to the CuBr laser so it can easily be seen that the energy per unit wavelength is much higher for the CuBr laser system in the region of best absorption for the two target chromophores. The CuBr laser produces radiation at wavelengths which specifically contribute to the destruction of the target chromophore. In contrast IPLs emit a broadband of wavelengths, most of which are not absorbed by the target chromophore and are therefore wasted or generate undesirable side effects

Case Studies:

To reinforce the assertion that a single treatment is the norm for a CuBr laser, a number of case studies are presented:

Vascular lesions: A single treatment using Yellow light

Skin rejuvenation:
One treatment using Yellow light

Pigmented lesions: A single treatment using Green light

Bulky lesions such as Seborrhoeic Keratosis cannot be treated with contact type systems.
However the CuBr laser can combine both yellow and green wavelengths in non-contact delivery mode to produce enough energy to coagulate these very common lesions which require only a single treatment.

Seborrhoeic Keratosis:
A single treatment with combined yellow and green light from a copper bromide laser

(not possible with an IPL)

In these applications it is absolutely critical that an appropriate wavelength and energy level (dose) is used to optimise the efficacy of treatment.

It is even less desirable to deliver adequate total energy using low power and very long delivery times (energy = Power x Time) grossly exceeding the thermal relaxation period. This type of treatment is no better than a non selective burn. Because the CuBr laser only emits at optimal wavelengths it is possible to set the energy to the required level to target only the selected chromophore rather than indiscriminately bombard all chromophores with inappropriate energy levels.
It is this ability to selectively target chromophores (lesions) which makes the CuBr laser a most successful skin rejuvenation system. The addition of contact hand-pieces and a contact scanner have increased the range of therapeutic efficacy to include the treatment of stretch marks and wrinkle reduction.

Skin Cooling:
To avoid collateral thermal damage and unwanted side effects to the epidermis by non-specific wavelengths of light, many IPL devices require dynamic skin cooling. For skin rejuvenation and the removal of thread veins and epidermal pigmented blemishes, no skin precooling is necessary when using the CuBr laser. Normal post-treatment erythema (redness) will disappear within 30-60 minutes and relief can be accelerated by using cooling gel packs.

Eye Hazard:
Finally, it is also mistakenly believed by some, that the IPL is less of an optical hazard to patients and operators. Recently presented research has demonstrated that a typical IPL fired directly at the human eye from 20cm would exceed the maximum permitted exposure (MPE) value by over 2000 times! Moreover, the size of an IPL aperture compared to that of most lasers would result in a much larger retinal burn and consequential possible loss of a larger area of vision. As a result of the broad band of wavelengths emitted it is not feasible to protect the eye of the operator without making visualization of the field of treatment virtually impossible. Many IPL users have to resort to closing their eyes each time they fire the IPL! In contrast, because the CuBr laser emits only at two wavelengths these can be filtered out with suitable glasses leaving the field of view available to all other wavelengths and clearly visible.

Conclusions:

- CuBr laser offers optimal wavelengths and energy densities for single-step photorejuvenation and treatment of vascular and pigmented lesions without skin cooling or unacceptable patient discomfort or side-effects.
- IPL light sources can be effective in permanent hair reduction but require multiple treatments to demonstrate any significant effect in photo-rejuvenation.
- Papular lesions like seborrhoeic keratoses, benign nevi, skin tags, angiofibromas and others and larger telangiectasia cannot be treated effectively with IPL
- Collagen neo-genesis using IPLs sufficient to demonstrate wrinkle reduction

by objective, evaluation remains largely unproven.

- IPL devices cannot be considered eye-safe and should be treated with the same safety precautions as Class 4 lasers.

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