PAPER

J R Coll Physicians Edinb 2007; **37**:300–304

Cutaneous applications of medical lasers and intense pulsed light systems

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ABSTRACT Medical lasers and IPL systems are currently used for a wide variety of cutaneous applications, such as the treatment of vascular lesions, unwanted hair, tattoos, scars, melanocytic and other skin lesions.[1] Accordingly, with the emergence of numerous new facilities from the hospital to the high street, it is important that healthcare professionals and patients should have appropriate awareness of treatments with these modalities. The aim of this review is to discuss the efficacy of commonly used skin lasers and IPL systems together with the indications for their use in treatment.

KEYWORDS Cutaneous lasers, vascular lesions, hair removal, melanocytic lesions, tattoos, scars, intense pulsed light

LIST OF ABBREVIATIONS Intense pulsed light (IPL), port wine stain (PWS), potassium titanyl phosphate (KTP), polycystic ovarian syndrome (PCOS), randomised controlled trial (RCT), yttrium aluminium garnet (YAG)

DECLARATION OF INTERESTS No conflict of interests declared.

Published online ***July 2007***

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PRINCIPLES OF LASER OPERATION

A laser emits a narrow beam of high intensity, monochromatic (single wavelength) light. Its use in the treatment of a skin condition is based on the principle of 'selective photothermolysis'.[2] Pulses of laser light directed at the skin may be selectively absorbed by chromophores such as haemoglobin, melanin or water. Absorption of light by a chromophore may either destroy the chromophore directly or promote a secondary response in the local area. Thus, the choice of which laser to use must be made carefully in order to achieve the desired effect with minimal impact on the surrounding tissue. For example, vascular lasers emit light that is strongly absorbed by the chromophore haemoglobin, and may cause thermal damage to blood vessels with subsequent colour fading. Light from epilatory lasers is strongly absorbed by the chromophore melanin, and may cause thermal damage or destruction of hair roots. Q-switched lasers generate extremely short, high power pulses of light which may fragment the chromophore melanin within melanocytic lesions or some tattoo pigment chromophores allowing removal by inflammatory cells. Laser light from ablative lasers is strongly absorbed by the chromophore water and consequently may be used to remove superficial layers of skin. Table I lists the typical applications of a variety of common cutaneous lasers.

The optimal duration of the pulses of light emitted from a given laser is determined by the physical properties of the chromophore. It is important that any thermal effect of the laser is effectively confined to the chromophore. Consequently, the pulse duration of the laser light must be less than the time taken for the chromophore to cool down to the level of the surrounding skin, a quantity known as thermal relaxation time. In general, narrow blood vessels have shorter thermal relaxation times than wide blood vessels and thin hair follicles have shorter thermal relaxation times than thick ones.

There has recently been increasing interest in the use of IPL systems as an alternative to lasers. Although there are some similarities between these devices, there are also important differences. Intense pulsed light systems will be discussed later in this review.

VASCULAR LESIONS

Currently, lasers usually offer the best treatment for the most common vascular malformation, known as the port wine stain. The pulsed dye laser is most widely used for PWS treatment, although KTP or Neodymium YAG lasers are also considered to be effective vascular lasers by many practitioners.[3] The chromophore haemoglobin present in these lesions strongly absorbs light from these lasers resulting in thermal damage to blood vessels and subsequent colour fading. Clinical purpura lasting for up

Laser	Abbreviation used in text	Applications	Wavelength (nm)	Chromophore
Potassium Titanyl Phosphate	KTP	Vascular lesions, scars	532	Haemoglobin
Pulsed Dye	PDL	Vascular lesions, scars	585-595	Haemoglobin
Diode	*none*	Hair Removal	670-1551	Melanin
Ruby	*none*	Hair Removal	694	Melanin
Q-Switched Ruby	*none*	Melanocytic Lesions, tattoos	694	Melanin, tattoo pigment (black, blue, some green)
Alexandrite	*none*	Hair removal	755	Melanin, tattoo pigment
Q-Switched Alexandrite	*none*	Tattoos	755	Tattoo pigment (black, blue, green)
Neodymium Yttrium Aluminium Garnet	Neodymium YAG	Vascular lesions, scars, hair removal	1064	Haemoglobin, melanin
Q-Switched Neodymium Yttrium Aluminium Garnet	Q-Switched Neodymium YAG	Pigmented lesions, tattoos	1064	Tattoo pigment (blue, black (red and orange when frequency doubled))
Erbium Yttrium Aluminium Garnet	Erbium YAG	Scars, other contour problems	2940	Water
Carbon Dioxide	*none*	Scars, other contour problems	10600	Water

TABLE 1 Common cutaneous lasers.

to fourteen days, caused by red blood cells escaping through puncture holes in thermally damaged vessel walls, was formerly an inevitable by-product of successful vascular laser treatment. However, with the manufacture of lasers with longer pulse widths, and consequently fewer explosive thermal effects, this may now be avoided. The duration of these longer pulse widths is still shorter than the thermal relaxation times of many blood vessels, and so the thermal effect remains confined predominantly to the vessels themselves. Nevertheless, the efficacy of treatment with the pulsed dye laser is usually greatest when accompanied by purpura. Vascular laser treatment is not suitable for patients with Fitzpatrick skin type six, or indeed for patients with a suntan, and must be used with caution for patients with Fitzpatrick skin type five, as depigmentation of epidermal melanin is possible. Hyperpigmentation, which can persist for twelve months or longer, is unusual, and most commonly accompanies lower leg treatments. Blistering and scarring are rare.

Superficial PWSs respond best to laser treatment. Whereas total clearance is unusual, considerable reduction in the contrast with surrounding skin is likely. It is reasonable to expect some fading in most deeper PWSs following laser treatment, although this will be limited due to the bulk of the lesion extending beyond the effective depth of penetration of the laser light. The majority of UK practitioners consider two to three months to be the optimum interval between treatments.[3] In PWSs resistant to ongoing treatment with one type of laser, further colour reduction may occur with other vascular lasers.[4] Treatment of leg telangiectasias with pulsed dye and Neodymium YAG lasers has also been performed with varying success dependent upon vessel morphology and depth.[5] Facial telangiectasias are easily treated with the pulsed dye laser.

Haemangiomas of infancy (strawberry naevi) differ from other vascular malformations in that they tend to regress spontaneously in most patients and are therefore not generally suitable for laser treatment unless they are life or organ threatening. Indeed, it has been shown in a RCT that treatment with the Pulsed Dye laser in uncomplicated haemangiomas is actually no better than a 'wait and see' policy.[6]

HAIR REMOVAL

Epilatory laser treatment may be suitable for patients with endocrine disorders, hairy naevi, hair bearing skin grafts, or recurrent pilonidal sinus as well as for cosmetic hair removal. Melanin in the hair is damaged or destroyed as it absorbs light from a Ruby, Alexandrite, Neodymium YAG or Diode laser.[7] Laser treatment is therefore appropriate for dark hair, but not suitable for white, grey or blonde hair. Patients with pale skins are especially

good candidates for this treatment. Some absorption of laser light will occur within the epidermal melanin. This is especially likely in patients with higher Fitzpatrick skin types, or who are suntanned, giving rise to the possibility of blistering, prolonged erythema, hyperpigmentation, hypopigmentation or even scarring.[8] Neodymium YAG, Alexandrite and Diode lasers can provide deeper light penetration than the Ruby laser (due to their longer wavelengths) but with less selective absorption by melanin and are therefore preferable for use in patients with higher Fitzpatrick skin types. Total hair removal is a rare outcome following laser treatment, and especially so in patients with endocrine disorders such as PCOS, but long-term reduction in hair density or coarseness is often achievable. Patients must be made aware at the outset that this may require multiple treatments.[9]

An RCT investigating repeated Alexandrite laser treatments for women with PCOS reported significant decreases in self-reported severity of facial hair and time spent on hair removal, as well as significant improvements in anxiety and depression scores, and quality of life.[10] Similar improvements in hair control have been observed with Neodymium YAG laser treatment. Laser treatment of the natal cleft, predominantly with an Alexandrite laser, has been shown to be a potential alternative to surgery for patients with pilonidal disease.[11]

MELANOCYTIC LESIONS

Malignant or pre-malignant melanocytic lesions should undergo excision biopsy and are not appropriate for laser treatment. Suspicious melanocytic lesions should be biopsied and only considered for laser treatment if histologically benign. Obviously benign melanocytic lesions, such as café-au-lait spots, freckles or 'liver spots' may be candidates for laser treatment. Histological examination of the lesion depth may be helpful for predicting the likely penetration of laser light and consequent outcome of treatment. Q-switched Neodymium YAG treatment of solar lentigines has been shown to be more effective and have fewer adverse effects than cryotherapy.[12] The Q-switched Ruby laser is effective in treating epidermal melanocytic lesions, but has been considered controversial in the treatment of congenital melanocytic naevi as depigmentation may make any future diagnosis of malignant transformation difficult.[13] Pigmentation changes may occur following laser treatment for the treatment of melanocytic lesions. Hyperpigmentation is usually temporary whereas hypopigmentation is more likely to be permanent. Scarring is rare.

TATTOOS

Unlike melanocytic lesions where there is a single chromophore, tattoos may have a variety of chromophores and intricate multicoloured tattoos represent a challenge in laser treatment requiring the use of several lasers. Table I illustrates the particular tattoo pigment chromophores that may be amenable to treatment with a given laser. Some pigments may prove more difficult to deal with than others. For example, Ferrous oxide (red) or titanium oxide (white) pigment tattoos may darken with laser treatment and the possibility of using an ablating laser should be considered instead. In contrast, pigment clearance of 75% or more is likely for black or dark blue tattoos.[14] A test area is always advisable, both to indicate the response to laser treatment, as well as to identify any patients who may experience hypersensitivity to the tattoo pigments released during treatment. Some amateur tattoos have been considered more difficult to remove than professional tattoos as the pigment may be at more varied, and generally deeper, depth. However, a report investigating the use of Q-switched Alexandrite laser to remove blue/black tattoo pigment indicated little difference in the number of laser treatment episodes required.[15] Concern has also been expressed regarding the suitability of laser treatment for tattoo removal in patients with skin types five and six because of the presence of increased amounts of melanin. Nevertheless, successful treatment outcomes have been reported in this population.[16] Hyperpigmentation following laser treatment for tattoo clearance is relatively common but usually only lasts for a matter of months. Hypopigmentation is more unusual. Persistent changes in skin texture or scarring are rare. Conventional surgical procedures still play a part in tattoo removal, although skin grafting or even pedicled tissue transfer may be required to reconstruct the excisional defect.

SCARS AND CONTOUR PROBLEMS

Vascular lasers may prove helpful for reducing the redness or pruritus of hypertrophic or keloid scars. Pulsed dye laser treatment of hypertrophic and keloid scars has been reported to reduce redness and itching, and improve pliability.[17,18] Furthermore, the prophylactic use of pulsed dye laser to prevent hypertrophic or abnormal scarring has also been recommended.[19] However, RCTs have yet to prove a clear advantage of pulsed dye laser over conventional treatments.

Ablative laser treatment may be used to reduce the physical profile of the scar, but it is not generally considered as an early intervention (before eighteen months) as the appearance of the scar may ameliorate with time. The contours of deep pitted scars, such as acne scars, may be improved but not removed.[20] Ablative laser treatment may be less traumatic and more precisely applied than dermabrasion, although there are no RCTs published. An ablative laser may also be the treatment of choice to improve the contour of benign lesions including tuberous sclerosis, epidermal naevi, syringomata and rhinophyma, especially for large areas that would

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otherwise require a graft.[21] Ablative laser treatments will usually require the use of a local or general anaesthetic. The Erbium YAG laser allows more subtle sculpturing of tissue than the Carbon Dioxide laser although, as it causes less residual thermal damage, bleeding can be a problem.[22] Dressings are often required for over a week after ablative laser treatment; erythema lasts on average for four weeks, and temporary hyperpigmentation is a common side-effect.[23] Permanent hypopigmentation may also occur.

INTENSE PULSED LIGHT SYSTEMS

Intense pulsed light systems are often considered as a cheaper alternative to lasers although there are few studies that compare their treatment efficacy.[24] Intense pulsed light systems deliver a band of wavelengths in contrast to the monochromatic light emitted from lasers. The chromophores melanin and haemoglobin absorb light from a variety of wavelengths and are therefore amenable to photothermolysis with an IPL system. However, IPL systems are less specific than lasers in their delivery of light energy to the required chromophore. As a result, the surrounding cutaneous tissue absorbs a greater proportion of the delivered light and cooling devices are often needed. Sustained erythema also appears to be a more common side effect with IPL due to the greater densities of energy required for treatment. Other side effects that are reported at varying rates for IPL procedures include blistering, hyperpigmentation, hypopigmentation, oedema and scarring. As with laser treatment, patients with higher Fitzpatrick skin types are most susceptible to these side effects. Nevertheless, IPL systems may offer more flexibility than some lasers in the selection of pulse durations or in the ability to deliver trains of pulses. The selection of appropriate pulse widths may then enable thermal destruction of the chromophore whilst limiting thermal damage to the surrounding cutaneous tissue. The light delivered from one pulse of an IPL system covers a much greater skin surface area than would be possible with any laser and, as a result, treatment with an IPL system is quicker. The increased area of light delivery with an IPL system can also be a disadvantage, however, as treatment with the device is less spatially specific than treatment with a laser.

Hair removal with IPL treatment is suitable for a similar group of patients as epilatory laser treatment.[25] Light from the IPL system is absorbed by melanin in the hair and hence it is most suitable for the removal of dark hair in patients with pale skins although the use of IPL for hair removal in patients of all Fitzpatrick skin types has been reported.

Good clinical results have been reported in the use of IPL for superficial telangiectasias.[26] In a comparison of treatments of telangiectasias, leg veins and cherry angiomas with an IPL system and a Neodymium YAG laser, patients with superficial lesions were more satisfied with the IPL system whereas patients with deeper lesions were more satisfied with the Neodymium YAG laser.[27] Treatment of all but the most superficial PWS is likely to be more effective with a vascular laser than with an IPL system.

Intense pulsed light is often an effective treatment for obviously benign superficial melanocytic lesions such as café-au-lait spots.[28] However, it is less suitable for obviously benign deeper melanocytic lesions and the use of a laser for treatment of these lesions should be considered instead.

Intense pulsed light is also effective for nonablative skin rejuvenation such as cosmetically improving the texture or smoothness of skin.[29] Although the effect of treatment with IPL is far more subtle than that with an ablative laser, the procedure is much less invasive and dressings are not required afterwards.

CONCLUSION

A wide variety of conditions may benefit from appropriate treatment with a suitable laser or IPL system and although there is a sizeable body of evidence to support the use of cutaneous lasers and IPL systems there are few RCTs. Laser treatments may be offered by Dermatology or Plastic Surgery Departments which will not usually have all the lasers mentioned in this review or an IPL system. Experienced units will be able to advise on whether a patient may benefit from laser or IPL treatment and identify what is the most appropriate device to use.

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