CASE REPORTS

Q-switched Ruby Laser Treatment of Benign Pigmented Lesions in Chinese Skin

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Abstract

The Q-switched ruby laser has been demonstrated as an effective choice of treatment for a range of benign pigmented lesions. Its wavelength of 694 nm enables deep penetration of the skin allowing the treatment of both epidermal and dermal lesions. However, this wavelength is selectively absorbed by melanin thereby enabling efficient targeting of the lesion's melanocytes. By utilising a Q-switched pulsewidth of 25 nanoseconds, thermal conduction into surrounding tissues is minimised.

Lesions such as nevus of Ota, chloasma, lentigines and cafe au lait have been successfully treated with energy densities ranging from 6 to 12 J/cm². Four case histories are described in this report. The clinical evidence indicates that pigmented lesions in Chinese skin must be treated with energy densities higher than those used in Caucasian skin to minimise the incidence of hyper-pigmentation. Typically, lesions require a small number of treatments, usually within the range one to six, to effect complete removal. The technique is easy to apply, with no need for anaesthesia, in many cases.

Keywords: Laser-tissue interactions, Melanocyte, Photo-mechanical reaction, Selective absorption, Vacuolation

Introduction

The occurrence of pigmented lesions in Chinese skin is very common, as high as 80-90% for certain conditions in females. This appears to be due to a number of factors including sun-induced changes, skin composition and also possibly diet/cooking habits. A number of techniques have been used for many years to remove these lesions with varying degrees of success. The recent application of the Q-switched ruby laser has proven to be a major success with a range of lesion types.[1,2]

All lesions treated by any type of laser must be benign since it is impossible to know if any potentially malignant cells will remain following laser treatment. This, therefore, limits the types of lesions which may be treated by this method but these still represent a large number.

Many lasers are now being used to treat pigmented lesions of the skin. This is possible due to the broad absorption profile of melanin across the visible part of the spectrum, thereby allowing almost any visible laser to induce some kind of reaction within the melanocytes.[3] While some of these lasers possess suitable wavelengths, some of them are limited in their applicability and by their pulsewidths.[4] This topic will be discussed in more detail in a later section.

Unlike vascular lesions which require a photo-thermal reaction to induce necrosis, pigmented lesions are thought to require a combination of both a photo-thermal and a photo-mechanical process. The latter reaction induces the formation of a pressure- or shock-wave at the surface of the melanin granules within the melanosomes causing these to fracture. This results in the melanocyte becoming dysfunctional while leaving the surrounding compliant tissue relatively undamaged. A little thermal coagulation may occur in the immediate vicinity of the melanocyte but this does not usually lead to gross skin damage. The process is similar to that in the treatment of tattoos by this laser.[5]

CHOICE OF LASER PARAMETERS

Most of the melanin in normal skin resides in the thin basal layer at the dermal-epidermal junction. In pigmented lesions, however, this is not the case since the large amounts of melanin may be found throughout the epidermis or dermis, depending on the type of lesion. The nevus of Ota typically contains melanin through the depth of the dermis whereas cafe au lait lesions are generally located only in the epidermis. This distinction is very important when considering laser treatment of these lesions since not all lasers are capable

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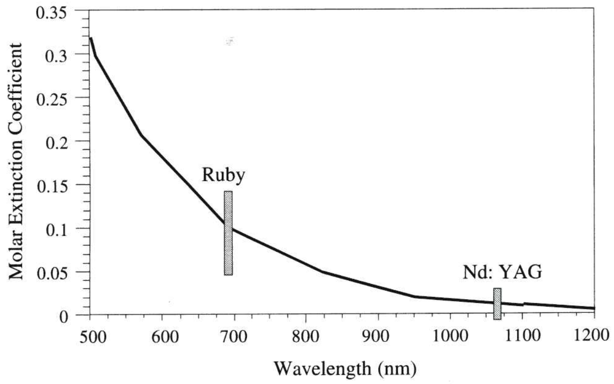


Fig. 1. Melanin extinction profile showing the ruby and Nd:YAG wavelength positions. Note that the ruby laser energy is absorbed approximately 3.6 times more efficiently than Nd:YAG energy.

of doing so. The reason for this lies in the melanin absorption profile (Fig. 1).

CHOICE OF WAVELENGTH

Melanin absorbs light across the whole of the visible spectrum, from 400 nm (blue light) to 700 nm (red light). However, this absorption decreases as the wavelength increases which has an important effect on the way in which laser light interacts with the skin. In addition, the epidermis and dermis possess absorption and scattering characteristics which are also dependent on the wavelength of the incoming light.[6-8] The combined effect of these processes is clearly demonstrated when laser light is used to treat lesions of the skin.

Much work has been done with the treatment of vascular lesions by lasers.[9,10] The results of this work have yielded a reasonable understanding of the laser-tissue interaction for a number of laser types. These include the argon, pulsed and continuous dye and the copper vapour lasers. Theoretical studies have revealed the importance in choosing the 'correct' laser parameters when considering treatments such as the wavelength, pulsewidth and spot size.[11,12] Using the knowledge built on the treatment of vascular lesions, the same theories may be applied to the laser treatment of pigmented lesions.

The choice of wavelength has two major implications. The first of these is directly related to Figure 1 in that the amount of absorption of laser energy is determined by the wavelength. Therefore, more light energy at 500 nm will be absorbed compared with light at 600 nm at some particular depth. At first this may seem to favour the shorter wavelengths for this application but at this point the second implication comes into account. Due to the general absorption and scattering processes within the skin, as a whole, red light can penetrate deeper into the skin than blue light. Therefore, the initial choice of a blue laser output is no longer so attractive since this would only allow an effective treatment of the more superficial lesions but not the deeper, dermal lesions.

Hence, a wavelength which allows deep penetration of the skin coupled with sufficient absorption by the melanin is required to maximise the range of lesions which may be treated.

CHOICE OF PULSEWIDTH

The next parameter to consider is the laser pulsewidth. This dictates how quickly or slowly the laser energy is absorbed by the melanin. A slow absorption (i.e. a long pulse) will allow any heat build-up to conduct into surrounding tissues which may result in unwanted thermal damage. Such damage may lead to fibrosis and scar tissue formation. Obviously these need to be avoided and so a suitably short pulse should be used. A short pulse will cause the laser energy to be absorbed relatively quickly by the melanin thereby reducing the likelihood of thermal conduction.

By using a Q-switched laser output, the pulsewidth can be reduced to tens of nanoseconds (1 nanosecond = 10^{-9} s). Such short pulsewidths result in minimal conduction within the skin which in turn results in very rapid localised temperature increases. The temperatures attained may be several hundred or even thousand degrees Celsius at the surface of the absorbing chromophore, in this case the melanin granule. However, these temperature gradients exist for very short timescales and they collapse to induce localised shockwaves. As these shockwaves propagate outwards from the chromophore, they cause any nearby brittle tissues to fragment while leaving compliant tissue unaffected. This process is known as a photo-mechanical reaction.

Some of the absorbed energy causes local tissue water to evaporate causing the creation of steam pockets around the melanocytes. This is evident immediately following irradiation of the lesion as a white patch approximately the same size as the laser spot. This process is initially a photo-thermal reaction leading to a mechanical response.

It is thought that a combination of the above processes may be required to induce clearance of a pigmented lesion.

CHOICE OF SPOT SIZE

Computer modelling of the effect of laser beam diameter in the interaction processes within the skin has revealed that even this parameter must be considered carefully.[13] These researchers have shown that the skin attenuates small laser beam diameters (around <0.5 mm) more efficiently than larger diameters. This is due to increased scattering effects in skin which are more prevalent with small beam diameters. The result of this effect means that less energy will penetrate the skin when small beam diameters are used. Hence some lasers which may have suitable wavelengths might not be able to treat deep lesions if only a small spot diameter is available.

Other factors which will determine the outcome of any treatment will generally be attributable to the physical make-up of the lesion, in particular its depth and thickness. However, these parameters may not be influenced by the clinician whereas the choice of the above laser parameters may be.

Materials and Methods

A Derma-Lase DLR-1 ruby laser was used in this study in the Mainz Body Clinic, Taipei. Its wavelength of 694 nm and pulsewidth of 25 ns comply well with the above requirements. A spot size of 5 mm at the patient surface was used for each treatment, again complying with the above requirements. Laser pulses were placed contiguously on the lesion with a slight overlap of around 0.5 mm. This overlapping procedure did not appear to cause any problems either during or after the treatment. Safety goggles were worn by all personnel, including the patient, in the treatment room at all times when the laser was active. This is very important since eye damage can occur even with a small amount of reflected laser energy if goggles are not worn.

The patients were selected according to lesion type. Only those patients with benign lesions were treated. All patients with any possibility of malignancy were directed to alternative treatments. The lesion types treated included nevus of Ota, cafe au lait, chloasma, epidermal melanosis and lentigines.

An immediate whitening reaction occurred in all patients following irradiation which corresponded to steam vacuolation within the epidermis. Occasional surface pinprick haemorrhaging and/or sub-surface bruising occurred in a small number of patients, particularly those with darker lesions, although these usually cleared within three days. This is thought to be caused by the photo-mechanical shockwave inducing some superficial capillaries to fracture due to their proximity to melanocytes. However purpura, as observed following pulsed dye laser treatment of vascular lesions, was not evident in any case. The standard weal and flare response usually occurs within minutes of the treatment.

Treatment energy densities generally started in new patients at 6 J/cm^2. If no whitening reaction was observed, the energy density was increased by approximately 1 J/cm^2 increments until whitening did occur. Generally lighter lesions required energy densities in the range of 6-9 J/cm^2 while darker lesions needed up to 12 J/cm^2 to induce the desired endpoint.

No anaesthesia was used since the treatment is not considered painful by patients. It is typically described as a sensation similar to an elastic band being snapped against the skin.

Results

CASE 1

Figures 2(a) and 2(b) show a young (20 years old) female patient with a cafe au lait lesion before and after treatment with the ruby laser. An energy density of 6 J/cm^2 was applied in two sessions lasting approximately 20 min each. The sessions were six weeks apart. An immediate whitening response occurred which lasted for a few seconds. The result shown was photographed after the second treatment.

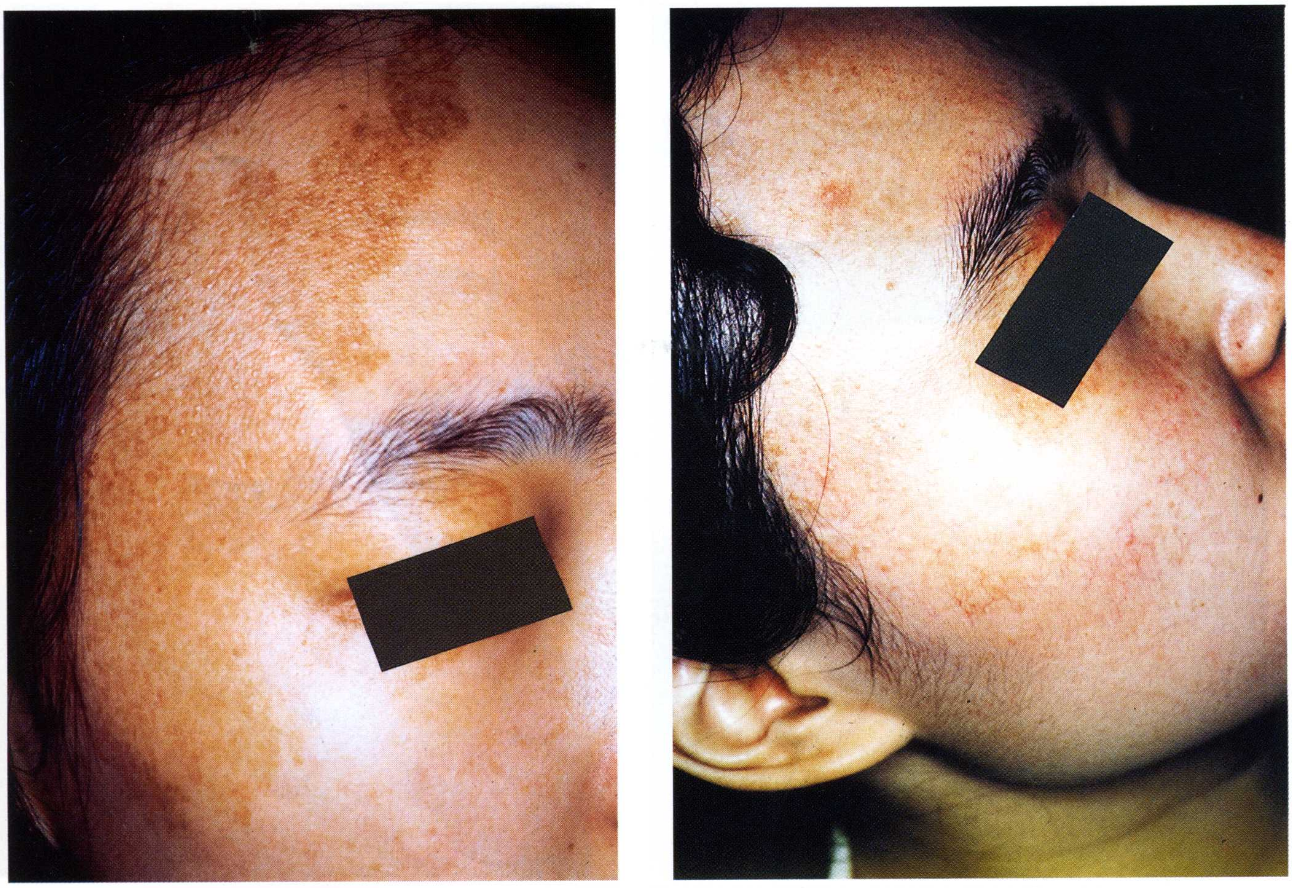
Most of the lesion has disappeared following these treatments although the patient will probably undergo one further treatment. The area immediately around the eye was not treated due to the lack of the specialised eye safety shields. The skin texture and tone was not affected by the treatments although some slight hypo-pigmentation was evident. The lesion has not yet recurred but the patient is still under observation.

CASE 2

Another female patient (33 years old) presented with freckles with verruca planus (Fig. 3(a)). She was treated at 7, 9 and 10 J/cm^2 over three consecutive treatment sessions. The first two of these sessions were partial area treatments and were carried out over two days. The third session occurred nine days after the second session. Once again, an immediate whitening reaction was observed following irradiation. Two weeks later, the treated area appeared to be free of most of the lesion again with some slight hypo-pigmentation (Fig. 3(b)). This patient is currently under observation as there is some evidence of recurrence in some areas.

CASE 3

The female patient (48 years old) in Figure 4(a) presented with chloasma and lentigines on her left cheek. It was decided to compare the effects of the ruby laser against conventional treatment methods. Part of the lesion was treated with the laser while the remainder received chemical treatment via Retin-A, corticosteroids and hydro-quinone. After only one treatment at 5 and 7 J/cm^2 by laser, the lesion appeared to clear completely. Similarly the chemical treatment resolved the lesion. However, the patient was subsequently exposed to sunlight which resulted in a surprising reaction. The area treated by the chemical method began to show signs of recurrence while the laser-treated area did not. The follow-up photograph of the laser-treated area (Fig. 4(b)) was taken three months following treatment and shows no signs of recurrence. She is still under observation for any further indications of recurrence.



Figs. 2(a)(b). Female patient with cafe au lait before (left) and after (right) two treatments. An energy density of 6 J/cm² was applied during the treatment.

Figs. 3(a)(b). Female patient presenting with freckles with verruca planus (left). These required the range 7 to 10 J/cm² to effect clearance (right). However, some recurrence has been observed.

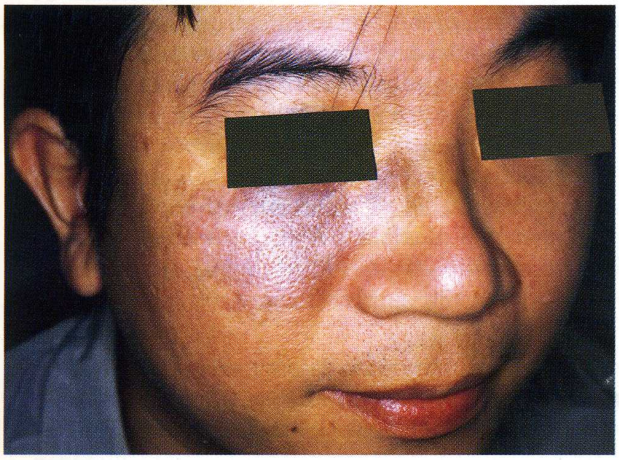
CASE 4

This male patient (39 years old) presented with a nevus of Ota (Fig. 5(a)) for treatment. The final result was obtained after six treatments with energy densities in the range 10 to 12 J/cm² with intervals of one to three weeks between treatments. The top layer of skin formed a scab after the first treatment which flaked off after around six days (Fig. 5(b)). No recurrence of the lesion has been observed to date.

Discussion

In general, superficial lesions were treated within a range of energy densities from 6 to 9 J/cm² while the deeper lesions required up to 12 J/cm² to effect removal.

Figs. 4(a)(b). This patient required treatment for chloasma and lentigines (left). Using energy densities of 5 and 7 J/cm², the lesion was effectively cleared after only one treatment (right).



Figs. 5(a)(b). Male patient with nevus of Ota. Six treatments were required with energy densities between 10 and 12 J/cm².

No lesions were treated above this energy density. It was found that superficial and lighter-coloured lesions typically required fewer treatments than the deeper, darker variety. Some lesions, such as lentigines and the lighter cafe au laits, required only one or two treatments at intervals ranging from one to four weeks. Deep lesions like nevus of Ota needed more treatment sessions

Fig. 5(b).

although this varied among patients. Scabbing occurred in some patients following irradiation. Unfortunately, some patients, particularly female, disliked the appearance of the scab and removed it themselves. It is felt that this removal has had a detrimental effect on the overall treatment and should be discouraged.

Hyper-pigmentation was evident in up to 25% of patients. This is thought to occur due to lower than required energy densities being applied to the lesions. These treatments appear to have resulted in stimulation of the melanocytes rather than their necrosis. Hence, hyper-pigmentation resulted in these patients post treatment. This incidence is higher than that reported following the treatment of Caucasian patients. The reason is probably due to the higher concentration of melanocytes in Chinese skin which may result in some of the deeper melanocytes being shielded from the incoming laser energy. However, these deeper cells may absorb sufficient energy to stimulate them into producing more melanin and hence lead to an increased probability of hyper-pigmentation. As a result, all the patients in this study are being monitored on a daily basis, where possible. Further work needs to be carried out to determine why the higher incidence of hyper-pigmentation occurs in this patient group.

The clinical results indicate that effective treatment may be achieved by the use of the Q-switched ruby laser without inducing scarring. Two unwanted side effects which have been observed are hypo- and hyper-pigmentation although the former of these was found to be transient in nature. Hyper-pigmentation appeared within days of the treatment and in some cases remained for a few months. Other researchers have indicated that this can persist for up to 12 months post treatment but that, in most cases, it disappears naturally. A suggested method for prevention of hyper-pigmentation involves the application of hydro-quinone on the lesion up to two weeks in advance of treatment. By blocking the enzymes involved in the production of melanin, it is thought that treatment-induced hyper-pigmentation may be avoidable. At the time of writing, this theory had not been tested.

Another side effect which occurred in a small number of patients was the appearance of telangiectatic vessels in the vicinity of the treated lesion. These were small and generally faded naturally over the course of two to four weeks. They generally appeared after any scabs had been removed. Interestingly there was a strong correlation between the appearance of these vessels and the subsequent appearance of hyper-pigmentation. If the vessels did not appear, hyper-pigmentation did not usually follow. This was particularly evident in lesions on the cheek and chin, however, hyper-pigmentation was never observed on the forehead. The reason for the appearance of these vessels is not yet fully understood.

The ruby laser appears to offer an excellent treatment modality for benign pigmented lesions, particularly in Chinese skin which is more prone to scar tissue formation than Caucasian skin. This fact negates the use of any laser which induces a photo-thermal reaction in the skin such as the carbon dioxide and argon lasers. These lasers are non-specific in that their wavelengths are not selectively absorbed by pigmented tissue whereas the ruby wavelength is well absorbed by melanin. However, the dermis is relatively transparent at this wavelength which allows penetration of the energy with little dermal absorption. The short pulsewidth produced by the Q-switching process prevents the possibility of conduction of heat around the melanocytes thereby reducing the likelihood of gross tissue damage.

The occurrence of hyper-pigmentation is a problem which requires further investigation although at this time, the extent of the problem is not known. Patients are currently being monitored to find the duration of the condition and whether the lesion recurs.

It is important to stress that only benign lesions should be treated by this method for the reasons given previously.

Conclusion

Further clinical studies are needed to quantify the numbers of treatments necessary and the most suitable energy density for each lesion type. However, as with tattoos and vascular lesions, there is a degree of variability between patients which cannot be predicted by the clinician. An important advantage of the ruby laser is that it is relatively difficult to induce permanent damage to patients' skin due to the nature of the laser-tissue interaction and the lack of thermal conduction into surrounding tissues. Hence it is a safe laser to use with little possibility of scar formation which means that relatively inexperienced users should not encounter any major clinical problems.

Other researchers seem to be in general agreement that the ruby laser currently offers the best modality for the treatment of these lesions.[1,2] The penetration of the ruby wavelength through the skin coupled with its very short pulsewidth appear to make it an excellent choice for the treatment of both epidermal and dermal lesions.

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