THE LASER APPLE: A NEW GRAPHIC REPRESENTATION OF MEDICAL LASER APPLICATIONS

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In the last decade the applications of the laser in surgery and medicine have increased dramatically. With the increase of indications has come a concomitant increase in possible classification of laser reactions, including the erroneous 'low power laser', 'high power laser' and others. The author presents a classification which is based on the laser/tissue reaction rather than on the hardware used to produce the laser beam. Laser/tissue reactions fall into two broad groups. When the tissue reaction to absorption of the incident laser energy results in photodestruction of, or an irreversible photomodulated change to the tissue architecture, then the level of reaction is higher than the survival threshold of the target cells. The author refers to this as high reactive-level laser treatment (HLLT), or more generally as *laser surgery*. On the other hand, the level of tissue reactivity to very low incident power and energy densities is well below the cells' survival threshold so that instead of being damaged the cells are directly activated by the low incident photon density. In this case the changes in the irradiated tissue are photoactive and reversible: the author refers to this group of reactions as low reactive-level laser therapy (LLLT), or more generally as *laser therapy*. In general when laser energy is incident on tissue, whether it is intended for laser surgery or laser therapy, it propagates into the target tissue in a wavelength-specific manner, but the resultant pattern, for example a HeNe laser viewed in a block of methylacrylate or an infrared laser viewed in vivo with a CCD camera, resembles very closely the shape of an apple. The author has used this basic apple shape and has modified it so that the 'Laser Apple' is capable of giving a range of information about the laser and its tissue effect, including the laser type, wavelength, output power, irradiated area, irradiation time and penetration depth: from these parameters the incident power and energy densities can be calculated. The apple itself can represent the scattering pattern and is capable of graphically demonstrating the range of tissue reactions which in turn give their name to the range of 'Laser Apples', such as the C-Apple (carbonization), V-Apple (vaporization) and A-Apple (activation).

Key words: Laser therapy, laser surgery, LLLT, HLLT, photoactivation, photodestruction

Introduction

Since its development by Maiman in 1960, the laser has found applications in many fields, including the field of medicine. In the past decade in particular, the applications of the laser in surgery and medicine have dramatically increased until it is true to say that almost every medical and surgical speciality has found a recognized

and valid application of the laser which offers specific advantages over current conventional methodology. With the increased use of the laser the terminology used to catalogue its effects has also increased, but the majority of the terminology is hardware-based, centering on the laser system used to produce the beam rather than on the reaction between the laser energy and the tissue it is aimed at. Such terms as 'high-power laser' or 'hard laser' and 'low-power laser' or 'soft laser' are all

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Manuscript received: July, 1996

Accepted for publication: August, 1996

Fig 1: Range of photothermal and nonthermal bioreactions generated by a laser beam when absorbed in target tissue, showing the classification of bioreactions into photodestructive reactions (laser surgical indications, HLLT) with approximate temperature ranges, and photoactivative reactions (laser therapeutical reactions, LLLT).

Fig 2: The fundamental 'Laser Apple' indicating physical laser characteristics (laser type, wavelength, output power, irradiated area, exposure time and range of penetration depth, allowing incident power and energy densities to be calculated) and tissue reactions (range of reactions and scattering pattern).

too often found in the literature. These terms are based only on the hardware, the laser, and the author feels they are neither clinically nor scientifically acceptable to describe what happens when a laser beam is incident on tissue, in other words the laser/tissue reaction.

The author has already presented his general classification of laser/tissue reactions into high-reactive-level laser treatment (HLLT, laser surgery) and low reactive-level laser therapy (LLL'T, laser therapy),^(1,2) where the 'level' in these terms represents the *level of*

reaction of the target cells to the incident laser energy. In HLLT the level of reaction is high, resulting in photodestruction and irreversible changes to the tissue architecture ranging from carbonization to protein denaturation. In LLLT the level of reaction is low, below the damage threshold of the target cells, and results in photobioactivation of the target cells and tissue to produce a range of beneficial therapeutic effects including amongst others enhanced wound healing, pain attenuation and accelerated repair to soft and hard tissue injuries. The above range of reactions and associated temperatures are summarized in Figure 1.

The author feels that these general classifications are too broad, and so in the present study presents a more detailed classification using graphic representations of subdivisions of the main classifications of laser surgery and laser therapy, based mainly on the tissue reaction but also including the scattering pattern and penetration depth of the beam in addition to full information on the beam parameters.

The Fundamental Laser Apple

The penetration depth and scattering pattern of a laser beam can be shown easily by observing the effect of aiming the beam from a visible light laser such as the HeNe (632.8 nm) perpendicularly at the top face of a translucent block of methylacrylate and observing the beam from the side of the block. In living or excised tissue the laser beam scattering pattern and penetration depth can be assessed using a charge-coupled device (CCD) digitizing camera of an appropriate wavelength specificity.⁽³⁾ Coupling this image with a suitable computer program can illustrate not only the penetration depth and scattering pattern, but the

relevant intensity of the beam, referred to by its creators as 'intensography'.⁽⁴⁾ In general, the scattering pattern of most laser wavelengths in living tissue roughly resembles the shape of an apple. The author therefore decided to base his graphic classification of laser reactions in medical and surgical applications on this apple shape, (Figure 2) which can show, in a single easily understood figure, the wavelength, the output power, the irradiated area, the exposure time, the laser device being used, and an approximate range of penetration

A-Apples

Fig 3: Examples of A-Apples showing the patterns produced by the GaAlAs diode laser compared with the visible light HeNe laser. In both cases all necessary parameters are given, including the range of approximate penetration depths, which will enable other clinicians to repeat the method with correct parameters.

depths as the incident laser parameters; additionally the range of bioreactions can be shown as already illustrated in Figure 1, together with the scattering pattern as the laser/tissue reactions.

Laser Apple Types

Following Ohshiro's classification of laser treatment into laser surgery and laser therapy, photodestruction and photoactivation, the fundamental Laser Apple can be subdivided into the activation apple (A-Apple) and the destruction apple (D-Apple).

The A-Apple

Figure 3a shows a typical example of an A-Apple, in this case representing a HeNe laser being applied for example in the accelerated healing of a non-healing ulcer. The wavelength (632.8 nm), the output power (15 mW), the irradiated area ($7.8 \times 10^{-2} \text{ cm}^2$) and the irradiation time (30 sec) are given, enabling the incident power density to be calculated at approximately 192 mW/cm^2 and the incident energy density at 5.76 J/cm^2 at an incident energy of 450 mJ. At the same time the scattering pattern is represented as a roughly apple-shaped area of photoactivation and the laser type is seen at the top of this pattern with the approximate penetration range. This one graphic illustration therefore summarizes all the relevant information. Figure 3b is an example of another A-Apple, in this case a GaAlAs diode laser being used for LLLT in pain attenuation at wavelength of 839 nm, an output power of 60 mW on a spot size of $(2 \times 10^{-2} \text{ cm}^2)$ for an irradiation time of 30 sec per point giving an incident power density of 3

W/cm^2 , an incident energy density of 90 J/cm^2 and an incident energy of 1.8 J. In this case, the penetration depth of the GaAlAs wavelength is known to be greater than the visible red HeNe beam, and this range is shown in the relevant position on the apple.

The D-Apple

In photodestructive applications in laser surgery the laser clinician uses a range of bioreactions to achieve the desired surgical effect, and thus there is a range of

Fig 4: A typical carbonization or C-Apple shape, in this case illustrating an argon laser being used for vaporization of a soft tumour. Note that carbonization is accompanied almost simultaneously by a complete range of photothermal and nonphotothermal reactions including photoactivation at the periphery of the beam.

THE D-APPLE GROUP

Fig 5: The D-Apple group, including the photothermal C-, V- H- and Pr- Apples (carbonization, vaporization, haemocoagulation and protein denaturation, respectively): note that concomitant with these reactions there that simultaneous LLLT occurs in the periphery of the beams. In addition two nonthermally destructive apple types are shown: the O-Apple, representing other destructive reactions such as photoacoustic, photoosmotic and photodynamic reactions, and the E-Apple which represents the photodissociative destructive effect of the excimer laser.

D-Apple types to represent these reactions. Figure 4 is a typical representation of the most destructive of the range of reactions, carbonization, which is concomitantly and almost simultaneously accompanied by vaporization, coagulation of both tissue and blood vessels, protein denaturation and photobioactivation as the incident power density is attenuated by the tissue through which the beam is passing: this is the C-Apple, and in the example shown an argon laser is being used in focused mode to vaporize, for example, a small, soft haemangioma simplex tumour. Because of the comparatively long irradiation times and the absorption characteristics of the 488-514.5 nm argon laser beam, there is a strong buildup of secondary thermal damage from conducted heat, hence the incidence of charring (carbonization) in the wound bed. The C-Apple is accompanied by other Laser Apples in the D-Apple group, namely the vaporization (V-Apple), haemocoagulation (H-Apple) and the protein denaturation (Pr-Apple) apples. Even though these are all D-Apples, the destructive reactions are accompanied at the periphery of the beam by simultaneous photoactivation, termed by the author simultaneous LLLT.

Also in the D-Apple group are two further apples which represent nonphotothermal destructive tissue

reactions. Other reactions apart from those mentioned above include those nonthermal reactions such as photo-osmotic, photo-acoustic, photochemical and photodynamic destruction: these are summed up in the O-Apple. The excimer laser has an apple all to itself because of its unique method of precise nonthermal photoablation through molecular dissassociation, represented as the E-Apple. The D-Apple types are summarized in Figure 5.

Discussion

The question of the correct use of terminology and its importance in the accurate reporting of clinical and surgical trials and experiments has been dealt with in some detail in the literature.⁽⁵⁻⁸⁾ Without accurate reporting and appropriate terminology other researchers are unable accurately to repeat clinical trials or experimental studies to corroborate data and validate findings. This leads to lack of scientific acceptance of the specific study or trial in particular and of the laser in surgery and medicine in general. Therapeutic applications of the laser tend to have more problems along these lines than surgical applications, mostly because laser surgery has a much longer history and is used in many more specialities than is the case with laser ther-

Fig 6: Laser Apples illustrating that a GaAlAs diode laser with a very low output power normally associated with A-Apple patterns seen in 6a is capable, with appropriate parameters, of creating an H-Apple pattern in the D-Apple group: 6b on the other hand shows a CO₂ laser with a comparatively high output power, normally associated with D-Apple patterns, creating an A-Apple pattern. Thus the terms 'high power laser' and 'low-power laser' are scientifically inaccurate and should be avoided in discussions regarding clinical laser applications.

apy. An example of current terminology which lacks a scientific base is the popular use of such terms as 'low power laser' and 'high power laser', or the marketing-driven and even more unscientific 'soft laser' and 'hard laser' to refer to therapeutic laser systems and surgical laser systems, respectively.

The author is of the opinion that while there may be lasers with low output powers and lasers with high output powers, they can actually both be used to produce an entire range of tissue reactions. Figure 6a demonstrates schematically in the Laser Apple format how a laser with a low output power is capable of producing surgical effects in target tissue, an H-Apple produced by appropriate parameters from a GaAlAs focused diode laser beam, and Figure 5b demonstrates that a laser with a high output power can be used to induce therapeutic effects in tissue when used with a sufficiently defocused beam, represented by the A-Apple. These apples demonstrate that a 60 mW laser beam incident on an irradiated area of $1.9 \times 10^{-5} \text{ cm}^2$ ($50 \mu\text{m}$ diameter spot) is capable of producing an actual incident power density of over $3,050 \text{ W/cm}^2$ which is certainly not a therapeutic beam, although it is being generated by what some authors erroneously insist on calling a 'low power laser'. By the same argument a 20 W CO₂ laser beam which is incident on an irradiated area of 78.5 cm^2 (10 cm diameter spot) produces an incident power density of approximately 250 mW/cm^2 , which is most certainly an incident beam with only therapeutic potential, but it is being generated by a 'high power laser'. The Laser Apples indicate these parameters simply and clearly.

The most important point the author wishes to stress is that the tissue *reaction* should be used to classify laser systems, and not any aspect of the hardware. A laser is merely the device which is capable of generating a beam of laser energy. It is the reaction with the tissue which gives this beam of special energy its clinical utility, whether for laser surgery or for laser therapy. That is why the author has designed the 'Laser Apple' concept so that a single pictorial representation is capable of giving all salient characteristics of a laser beam which not only includes all the physical parameters associated with the laser itself but also goes further and graphically represents the laser tissue reactions and the beam spread and penetration range. The latter must be given as a range because penetration varies depending on tissue type and the amount of any particular chromophore specific for the wavelength of the laser incident on the tissue. The author believes that when the laser clinician can report in one simple diagramme the entire range of parameters he or she has used, it is a necessary prerequisite so that other colleagues can easily see what parameters were used in order to repeat the work.

References

- 1: Ohshiro T and Calderhead RG (1988): Photobioactivation. In "Low Level Laser Therapy: A Practical Introduction." John Wiley & Sons, Chichester, UK. pp 32-38.
- 2: Ohshiro T (1991): "Low Reactive Level Laser Therapy: Practical Application." John Wiley & Sons, Chichester, UK.
- 3: Kato K and Nagasawa A (1991): Imaging technique for near infrared GaAlAs diode laser beam distribution in tissue. *Laser Therapy*, 3: 67-70.

- 4: Nagasawa A (1991): Applications of LLLT in dentistry. In Ohshiro T, "*Low Reactive Level Laser Therapy: Practical Application.*" John Wiley & Sons, Chichester, UK. pp76-98.
- 5: Ohshiro T and Calderhead RG (1988): Preface. In "*Low Level Laser Therapy: A Practical Introduction.*" John Wiley & Sons, Chichester, UK. pp xi-xii.
- 6: Ohshiro T (1990): Editorial, Terminology again. *Laser Therapy*, 2: 99-100.
- 7: King PR (1989): Low Level Laser Therapy: A Review. *Lasers in Medical Science*, 4: 141-150.
- 8: Calderhead RG (1991): Watts a joule: on the importance of accurate and correct reporting of laser parameters in low reactive-level laser therapy and photobioactivation. *Laser Therapy*, 3: 177-182.