Immediate skin responses to laser and light treatments

Warning endpoints: How to avoid side effects

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Learning objectives
After completing this learning activity, participants should be able to recognize warning endpoints for different laser applications; detail the laser tissue interaction underlying these responses; and select the appropriate endpoints to optimize safety.

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Lasers are versatile, commonly used treatment tools in dermatology. While it is tempting to follow manufacturer's guidelines or other "recipes" for laser treatment, this approach alone can be a recipe for disaster. Specific and immediate skin responses or endpoints exist and are clinically useful because they correlate with underlying mechanisms that are either desirable (ie, therapeutic), undesirable (ie, warning signs of injury or side effects), or incidental. The observation of clinical endpoints is a safe and reliable guide for appropriate treatment. This article presents the warning endpoints during specific dermatologic laser treatments, and the accompanying article presents the therapeutic endpoints, their underlying mechanisms, and the utility of these endpoints. (J Am Acad Dermatol 2016;74:807-19.)

Key words: adverse effects; endpoint; laser; light; skin; warning.

INTRODUCTION

Key points

- **Immediate or short-term tissue reactions, called endpoints, can provide a reliable indicator of desired treatment response or of unwanted tissue injury**

Abbreviations used:

IPL:	intense pulsed light
MTZ:	microthermal zone
Nd:YAG:	neodymium-doped yttrium aluminum garnet
RF:	radiofrequency
SP:	selective photothermolysis

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- **The specific endpoints vary with the type of laser, with proper use of the laser, and with the histologic target(s) involved**
- **Observation of clinical endpoints is crucial for the adjustment of laser parameters during treatment, both to increase efficacy and to avoid side effects**

Lasers and other energy sources are frequently used in dermatology to treat vascular lesions, hypertrichosis, tattoos, various pigmented lesions, scars, photoaging, and skin laxity (Table I). Of all surgical tools, lasers are both the most precise and the most selective. For many applications, there are specific "target" structures or distinct patterns of intended skin injury that achieve the therapeutic response without causing significant collateral injury or scarring. Different anatomic, physical, and physiologic mechanisms are involved in these various applications. As a result, specific immediate and early skin responses or "endpoints" are seen during various laser treatments that correlate with therapeutic outcomes. Other early responses are harbingers of unwanted injury or phenomena that lead to side effects.

We present the clinically useful early response endpoints and their mechanisms that arise during treatment with laser and other energy-based devices in dermatology. Knowledge of specific desired (ie, therapeutic) and undesired (ie, warning) endpoints is key for the proper clinical use of lasers in dermatology. The mechanisms underlying these early response endpoints are also fundamental to understanding laser–tissue interactions. There are 2 articles in this series; the current article presents the warning endpoints, following an overview of lasers, other energy sources, and their tissue interactions and laser safety. The accompanying article presents the specific therapeutic endpoints that are correlated with providing effective treatment.

LASER–TISSUE INTERACTIONS

Key points

- **Selective photothermolysis depends on the preferential absorption of light by the histologic target or chromophore**
- **The laser–tissue reaction in the histologic target produces a specific endpoint in the skin**
- **Nonselective devices produce nonspecific endpoints**

Light, radiofrequency, microwave, ultrasonography, plasma, and other sources that transfer energy into the skin produce their various effects based on the location, amount, and rate of energy absorption inside the tissue. The absorbed energy is converted to heat, mechanical motion, or chemical reactions. Most laser- and other energy–based treatments in dermatology work by creating heat within tissue at specific target locations or in specific patterns.

When using light sources, basic parameters that describe the dosimetry of treatment must be understood. These include wavelength of light (nm), pulse duration (in seconds), frequency of pulse delivery (Hertz [Hz]), energy (Joule [J]), fluence (the incident energy per unit area, J/cm^2), power (watts [W], the rate of energy delivery), power density or irradiance (the rate of incident energy delivery per unit area, W/cm^2) and exposure spot size (cm). For fractional lasers, the area density (ie, the fraction of skin treated, expressed as %) and pulse energy (ie, J per pulse, corresponding to depth of treatment) are also important.[84]

Many of the lasers used in dermatology affect specific light-absorbing "targets" (eg, blood vessels, pigmented cells, hair follicles, or tattoo ink) based on the process of selective photothermolysis (SP).[1,85] SP depends on the preferential absorption of light by the targets, provided by light-absorbing molecules called chromophores. For example, blood vessels are treated using hemoglobin as the target chromophores; melanin is the target chromophore for the treatment of hair and for various pigmented lesions; and tattoo inks or exogenous pigments are the chromophores for tattoo and traumatic tattoo removal. Flashlamp sources (intense pulsed light [IPL]) mimic lasers to some extent, using broad spectrum light through cutoff filters to target chromophores. By choosing different wavelengths of light, different chromophores are affected. IPL sources are generally less selective than lasers and may be associated with a greater number of side effects.[86]

For SP, a brief pulse of light is used to limit damage to the tissue surrounding the targets. By delivering the energy in a pulse, the light-absorbing targets become hot before much heat can diffuse into the surrounding tissue. This produces a specific reaction in the target chromophore and in the skin called an endpoint. The pulse duration is chosen to be about equal or somewhat less than the time needed for a target to cool, called the thermal relaxation time. Smaller targets cool faster and need shorter pulse durations for SP. Dermatologic lasers for SP span a wide range of pulse durations. For example, a tattoo ink particle (~0.05-1 μm) cools in <1 microsecond; nanosecond and picoseconds laser pulses are therefore used for tattoo removal. In contrast, a terminal hair follicle (~75-200 μm) takes several milliseconds to cool, such that 1- to 100-millisecond laser or IPL pulses are typically used for permanent hair