CO_2 Laser Therapy in Dermatology and Dermatologic Surgery

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The CO_2 laser is the most versatile laser used in the treatment of cutaneous lesions. It is unique in that it can be used for resurfacing as well as excisional and even incisional procedures. For the dermatologist, potential applications of the CO_2 laser essentially are limitless. The advent of the fractional CO_2 laser has opened new doors for additional implementations of the device and also has increased the safety profile for procedures such as full-facial resurfacing. This article provides a brief overview of both traditional and fractional CO_2 laser applications in dermatology and dermatologic surgery. *Cosmet Dermatol.* 2011;24:412-418.

The CO_2 laser is the most versatile and powerful laser available for the treatment of cutaneous lesions. Advances in both power and delivery have made the CO_2 laser a multipurpose device that is increasingly effective in dermatology and dermatologic surgery. The advent of fractional CO_2 delivery has led to improved efficacy in the treatment of rhytides and chronic solar damage with decreased downtime and risk. Similar to its traditional predecessor, the fractional CO_2 laser is being used for an increasing number of applications. A great deal of literature exists on the physics and applications of the CO_2 laser in the dermatology setting. This article provides a brief summary of some of the highlights of the CO_2 laser with an emphasis on its applications.

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LASER PHYSICS

The CO_2 laser emits light at 10,600 nm. Based on the principles of selective photothermolysis,[1,2] this light is readily absorbed by water, which is particularly important given that the skin is composed of more than 80% water.[1] Carbon dioxide laser light energy is absorbed within 20 to 50 µm of soft tissue[1]; therefore, knowledge of the tissue interactions caused by the device is imperative. The near-complete absorption of CO_2 laser energy yields rapid heating and tissue vaporization of intracellular water with subsequent tissue ablation.[1]

A basic understanding of laser physics is paramount to the safe and effective application of the CO_2 laser.[3] Laser light is characterized by collimation, coherence, and monochromaticity. Use of the CO_2 laser requires additional awareness of the power distribution within the impact spot.[3] Power distribution also is referred to as transverse electromagnetic mode (TEM). The most basic form ($TEM_{0,0}$) represents a Gaussian (normal) distribution, with approximately 86% of power contained within the spot of impact.[3,4] This TEM form highlights the relevance of adjacent thermal damage zones and

the importance of proper settings to minimize unwanted tissue injury.[1]

The CO_2 laser can be utilized in either continuous or pulsed delivery modes. The use of a continuous wave mode requires more energy and thus often limits the overall available power that a specific laser can produce. Pulsed delivery modes can be used in both continuous and noncontinuous wave lasers. The advent of ultrapulsed CO_2 lasers has enabled treatment at maximal power with lessened thermal damage.[1]

The parameter settings for the CO_2 laser depend on the delivery mode (continuous vs pulsed). For continuous wave CO_2, power is the primary setting and is measured in watts. Power density or irradiance (W/cm^2) can be calculated as follows: power output · 100 (mm^2/cm^2) / impact spot size (mm^2). This calculation is an approximation, as the $TEM_{0,0}$ mode represents approximately 86% of energy within the impact spot and not 100%.[1] Thus calculation of irradiance for a CO_2 laser using a 2-mm handpiece at 10 W is as follows: 10 W · 100 (mm^2/cm^2) / 3.14 · 1 (mm^2) = 318.47 W/cm^2. This calculation is particularly important given the different handpieces that are available for the CO_2 laser; for example, a 2-mm handpiece at 10 W delivers 3.14 W/cm^2; however, using a 0.2-mm handpiece at the same power yields 3184.71 W/cm^2. This incisional handpiece is well suited for excisional and/or incisional procedures. Additionally, the handpiece may be operated in a focused mode, yielding high irradiance and excellent cutting properties, or it may be used in a defocused mode, yielding a lower irradiance but better coagulative properties (Figure 1).[5] Time and duration are components in the measurement of power time or joules (W/s). Fluence (J/cm^2) accounts for all of these factors—impact size, power, time, duration—in the following formula: watts · seconds (duration of delivery) / area (of impact size).[3] Although these calculations likely would not be used by most laser practitioners, they demonstrate the importance of a thorough understanding of CO_2 laser physics for both efficacy and safety. This discussion is based on a focused beam; however, defocusing the beam can be performed to manipulate irradiance and is a highly effective means of treating a number of epidermal and dermal lesions.[1]

The net result of the possible laser-tissue interactions (direct reflection, indirect reflection, scatter, transmission, and absorption) is the total effect by that laser.[3] Approximately 5% of the laser light that hits the skin surface is reflected.[6] A laser impact with $TEM_{0,0}$ mode will result in a central zone of tissue vaporization.[3]

PREOPERATIVE CARE

Little preparation is needed for the skin during CO_2 laser surgery.[1,7-12] Eye protection for patients and personnel in the treatment room is essential, as the laser can damage the cornea. Proper door signage is needed to caution anyone outside the treatment room who may enter. Ocular protection for the patient typically includes metal corneal shields. Alternatively, metal goggles also may be used. Metal (nonreflective) corneal shields offer the highest level of protection. Proper sizing of the corneal shields is important to ensure that optimal protection is achieved. Ideally, corneal shields should not move freely once in place. The potential for reflection of the CO_2 laser warrants caution with reflective objects in the treatment room, including the corneal shields themselves. Patients and operators should remove reflective jewelry prior to beginning the treatment.[1] Overall, patients and operators should adhere to laser safety measures.[13]

Figure 1. The CO_2 laser was used in defocused mode to treat a plantar verruca. Note the smoke plume and smoke evacuator.

Patients with a history of fever blisters should receive oral prophylaxis against herpes simplex virus, which is commonly achieved by administering valacyclovir or acyclovir. A history of prior or current use of isotretinoin also should be noted, as cosmetic surgical procedures typically are not recommended for 6 months after isotretinoin use to avoid poor cosmetic scarring. Additionally, patients with a history of scarring and/or keloid formation should be cautious in pursuing treatment. Ultimately, the CO_2 laser is an excellent choice for treatment of hypertrophic scars and keloids; however, full-facial resurfacing with the fractional CO_2 laser should be performed with caution in higher risk patients.[14]

The CO_2 laser is an ablative laser and thus anesthesia is required for use, with options ranging from topical anesthetics to general anesthesia.[15] Small epidermal lesions may be treated with topical anesthetics only; however, treatment typically requires local anesthesia. Facial resurfacing can be performed using local anesthesia with or without nerve blocks, but monitored or general anesthesia may be preferred for patient comfort. An added benefit of local anesthesia is a low incidence of postoperative pain. A combination of topical and local anesthesia, nerve blocks, and monitored sedation offers optimal patient comfort and allows the surgeon to maximize treatment settings.

INTRAOPERATIVE CARE

The CO_2 laser is an ablative laser and therefore poses a fire hazard. Precautions include the use of moist or wet gauze and/or towels as well as avoidance of medical oxygen. Special precautions also must be used with general anesthesia, particularly near the endotracheal tube. Many offices also have a backup generator in the event of a power outage. Although loss of power does not necessarily pose an acute risk to the patient, a generator ensures that a procedure can still be completed in case of a power failure.

The laser plume has been proven to contain carbonized particles with potential carcinogenic and viral exposure.[1] Smoke evacuators that are held within 1 cm of the laser impact site can achieve more than 98% efficiency in plume removal; however, this efficiency drops by half when held at 2 cm.[16] The use of masks intended for operators of lasers and high-efficiency smoke evacuators is recommended, especially in combination with smoke evacuators.[1]

POSTOPERATIVE CARE

Although postoperative care for CO_2 laser treatment is not complicated, it is one of the most important components of the procedure. The surgeon must determine from the initial consultation if the patient is a good

Epidermal and Dermal Lesions Treated With the CO_2 Laser

- Acne keloidalis nuchae
- Acne scarring
- Actinic cheilitis
- Actinic keratoses
- Adenoma sebaceum
- Angiofibroma
- Angiokeratoma
- Basal cell carcinoma
- Brook-Spiegler syndrome
- Chondrodermatitis nodularis helicis
- Clear cell acanthoma
- Condyloma
- Cutaneous vascular lesions
- Darier disease
- Elastosis perforans serpiginosa
- Fordyce spots
- Granuloma faciale
- Hailey-Hailey disease
- Hidradenitis suppurativa
- Hydrocystomas
- Hypertrophic scarring
- Keloids
- Lichen sclerosus et atrophicus
- Linear epidermal nevus
- Lupus pernio
- Lymphangioma circumscriptum
- Matrixectomy (with nail avulsion)
- Milia
- Neurofibroma
- Nevoid basal cell carcinoma syndrome
- Pearly penile papules
- Porokeratosis
- Rhinophyma
- Rhytides
- Scar revision
- Sebaceous hyperplasia
- Seborrheic keratosis
- Stria cutis distensae
- Syringomas
- Tattoo removal
- Trichelemmoma
- Verruca
- Xanthelasma

candidate for CO_2 laser surgery. A patient who may not be compliant with postoperative care could jeopardize his/her results and develop serious postoperative scarring and/or infection. Postoperative wound care typically includes a moisture barrier such as Vaseline (Unilever) or Aquaphor ointment (Beiersdorf Inc). A multitude of adjunctive barrier creams and ointments exist and may be used based on physician preference. There certainly are as many different wound care regimens as there are surgeons using the CO_2 laser; however, most regimens typically involve daily cleaning with diluted hydrogen peroxide or vinegar water followed by generous application of Vaseline (or another agent).

Avoidance of sun exposure also is critical in the postoperative phase. Failure to comply with these instructions can lead to permanent scarring and/or diffuse infection; therefore, patients who are likely to be noncompliant are not optimal laser candidates. It is imperative to discuss postoperative care with the patient at the initial consultation to determine if he/she is likely to be compliant and is thus a surgical candidate.

INDICATIONS

The number of potential applications for the CO_2 laser continues to increase (Table).[1,17-43] The long list of uses demonstrates the utility of the CO_2 laser in a wide range of dermatologic entities. Recent advances in CO_2 laser delivery technique primarily have focused on the fractional CO_2 laser. This new method of delivery when applied to an older modality has benefitted from a tried-and-tested laser platform. A brief discussion of some of the many indications for both traditional and fractional CO_2 lasers follows.

The fractional CO_2 laser most commonly is used for the treatment of chronic solar damage and rhytides. It marks a highly effective technique that fills the void between chemical peels and surgical face-lifts. Fractional CO_2 delivery is based on the creation of a patterned grid that results in thousands of predictable surgical wounds (Figure 2). These wounds, known as treatment columns, contract as they heal to yield skin tightening (Figure 3). Fractional treatment has a resurfacing effect (Figure 4), as does the traditional CO_2 laser; however, the density of the treatment area can be precisely adjusted. Results from the fractional CO_2 laser have been impressive, with reports citing improvement of perioral rhytides by 81% to 99% and improvement of overall moderate to severe facial rhytides by 45% to 50%.[5,44-48]

Traditional CO_2 resurfacing previously was limited to the face; however, the advent of the fractional CO_2 laser has enabled the treatment of other areas such as the neck, chest, hands, forearms, and legs (Figure 5). Less-aggressive handpieces and delivery settings certainly have been beneficial in avoiding overtreatment and/or scarring of these areas.

Although the primary use of the fractional CO_2 laser is for the treatment of chronic solar damage and rhytides, it also has been effective in treating acne scarring. Fractional CO_2 laser therapy for the treatment of acne scars may be administered using the same techniques as full-facial resurfacing for rhytides, adding an additional treatment option to the dermatologist's armamentarium.

Traditional CO_2 laser treatment often is categorized as ablative and incisional. The ablative CO_2 laser essentially is the workhorse in the treatment of epidermal and dermal lesions (Figure 6). The use of a continuous wave in defocused mode provides an endless number of possible

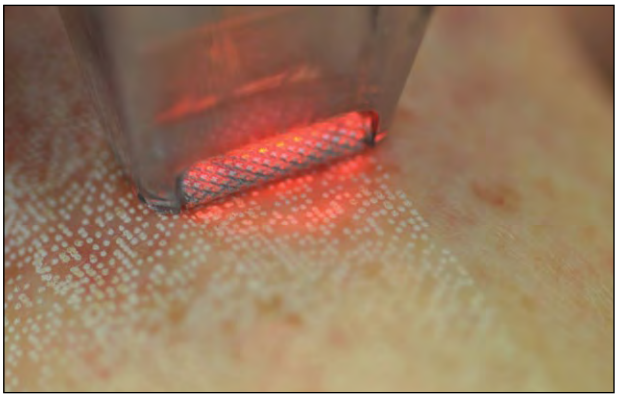

Figure 2. The fractional CO_2 laser was used to treat chronic solar damage on the dorsal hands.

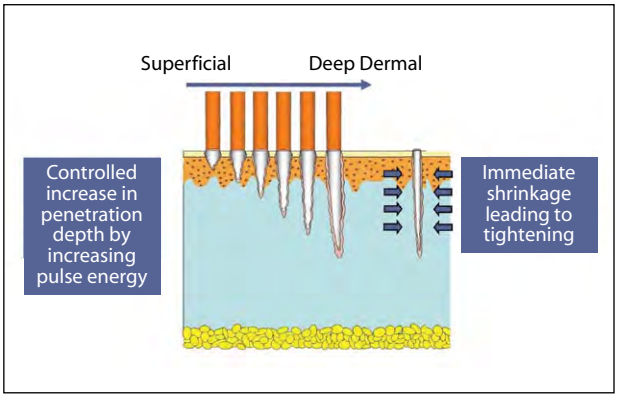

Figure 3. The fractional CO_2 laser produces controlled surgical wounds that subsequently contract to yield skin tightening. Pattern density and power are the primary parameters that are adjusted to control the outcome. Image courtesy of Solta Medical.

Figure 4. The face at baseline (A) and 6 weeks after fractional CO_2 laser resurfacing (B). Improvement typically continues for at least 3 months following treatment, often up to 6 months.

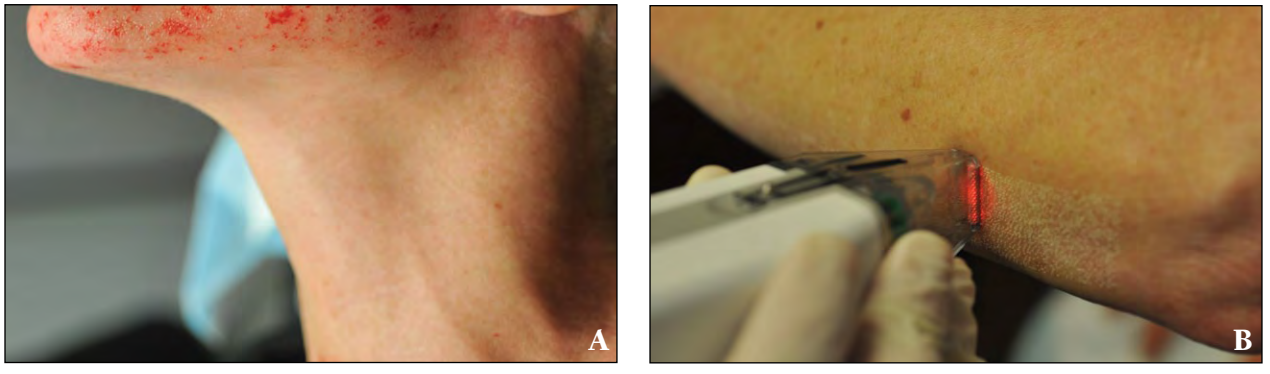

Figure 5. Fractional CO_2 laser therapy can be implemented in a multitude of nonfacial sites, including the neck (A) and forearms (B).

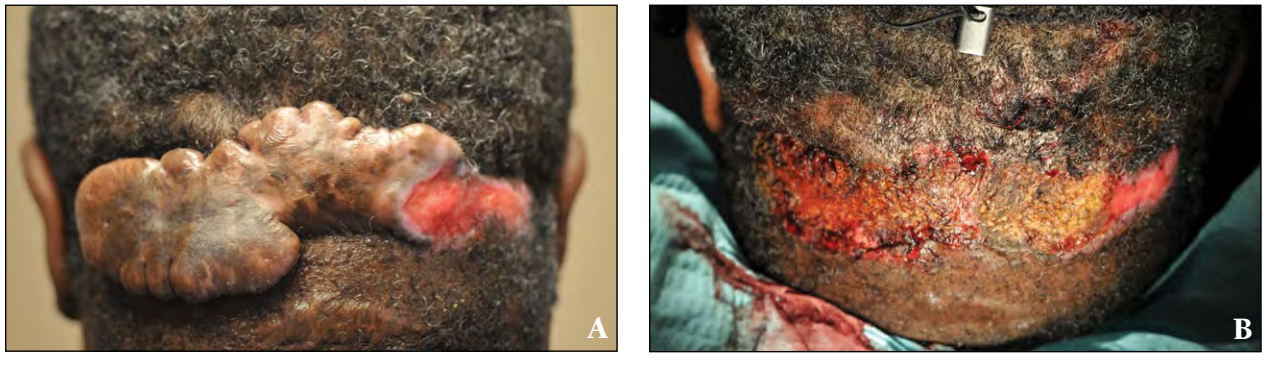

Figure 6. A patient with acne keloidalis nuchae before (A) and after treatment with the ablative and incisional CO_2 laser (B).

treatment indications (Table). The technique for treatment of these lesions does not vary; however, the operator must know and understand the settings to maximize efficacy and safety. Most dermatologic surgery clinics have a single CO_2 laser, perhaps with different handpieces. A typical ablative handpiece has a spot size of approximately 2 mm and can be used to treat almost any cutaneous lesion. The primary setting that can be adjusted on continuous wave mode is power, which is actually quite simple, as the operator may simply dial up or down the indicated power as needed. An understanding of the implications of spot size and power are important, as demonstrated by the difference in irradiance of a 2-mm versus a 0.2-mm spot size. A partial list of possible indications is summarized in the Table. The pulsed mode may be desired to achieve high power levels, in which case power and frequency need to be adjusted.

CONCLUSION

The CO_2 laser is one of the most powerful and versatile tools in the cutaneous surgeon's armamentarium. With traditional and fractional delivery options, the CO_2 laser offers a wide range of possible applications. Although the fractional CO_2 laser is commonly used at present, the opportunity to utilize the traditional CO_2 laser offers the surgeon multiple applications that can be used daily in the dermatology office.

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