CO₂ Laser Therapy in Dermatology and Dermatologic Surgery

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The CO₂ 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 CO₂ laser essentially are limitless. The advent of the fractional CO₂ 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 CO₂ laser applications in dermatology and dermatologic surgery. Cosmet Dermatol. 2011;24:412-418.

LASER PHYSICS

The CO₂ 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 CO₂ 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 CO₂ laser.³ Laser light is characterized by collimation, coherence, and monochromaticity. Use of the CO₂ 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 (TEM₀₀) 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 CO2 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 non-continuous wave lasers. The advent of ultrapulsed CO2 lasers has enabled treatment at maximal power with lessened thermal damage.1

The parameter settings for the CO2 laser depend on the delivery mode (continuous vs pulsed). For continuous wave CO2, power is the primary setting and is measured in watts. Power density or irradiance (W/cm²) can be calculated as follows: power output · 100 (mm²/cm²) / impact spot size (mm²). This calculation is an approximation, as the TEM0,0 mode represents approximately 86% of energy within the impact spot and not 100%.1 Thus calculation of irradiance for a CO2 laser using a 2-mm handpiece at 10 W is as follows: 10 W · 100 (mm²/cm²) / 3.14 · 1 (mm²) = 318.47 W/cm². This calculation is particularly important given the different handpieces that are available for the CO2 laser; for example, a 2-mm handpiece at 10 W delivers 318 W/cm²; however, using a 0.2-mm handpiece at the same power yields 3184.71 W/cm². 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).3 Time and duration are components in the measurement of power time or joules (W/s). Fluence (J/cm²) 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 CO2 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 TEM0,0 mode will result in a central zone of tissue vaporization.3

PREOPERATIVE CARE
Little preparation is needed for the skin during CO2 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 CO2 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 CO2 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 CO₂ laser is an excellent choice for treatment of hypertrophic scars and keloids; however, full-facial resurfacing with the fractional CO₂ laser should be performed with caution in higher risk patients.¹⁴

The CO₂ 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. 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

**INTRAOPERATIVE CARE**

The CO₂ 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.

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**POSTOPERATIVE CARE**

Although postoperative care for CO₂ 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
candidate for CO₂ 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 CO₂ 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 CO₂ laser continues to increase (Table). The long list of uses demonstrates the utility of the CO₂ laser in a wide range of dermatologic entities. Recent advances in CO₂ laser delivery technique primarily have focused on the fractional CO₂ laser. This new method of delivery when applied to an older modality has benefited from a tried-and-tested laser platform. A brief discussion of some of the many indications for both traditional and fractional CO₂ lasers follows.

The fractional CO₂ 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 CO₂ 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 CO₂ laser; however, the density of the treatment area can be precisely adjusted. Results from the fractional CO₂ 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 CO₂ resurfacing previously was limited to the face; however, the advent of the fractional CO₂ 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 CO₂ laser is for the treatment of chronic solar damage and rhytides, it also has been effective in treating acne scarring. Fractional CO₂ 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 CO₂ laser treatment often is categorized as ablative and incisional. The ablative CO₂ 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 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 CO2 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 CO2 laser is one of the most powerful and versatile tools in the cutaneous surgeon's armamentarium. With traditional and fractional delivery options, the CO2 laser offers a wide range of possible applications. Although the fractional CO2 laser is commonly used at present, the opportunity to utilize the traditional CO2 laser offers the surgeon multiple applications that can be used daily in the dermatology office.

REFERENCES
30. Doctoroff A, Oberlender SA, Purcell SM. Full-face carbon dioxide laser resurfacing in the management of a patient with the

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