In the past few years, there have been many reports demonstrating the effectiveness of carbon dioxide (CO₂) laser resurfacing of facial rhytides and acne scarring. The procedure has become a widely utilized technique, surpassing other currently available cosmetic treatments because of its increased availability and high degree of clinical effectiveness. The advantages of pulsed laser resurfacing are the precise control of tissue vaporization, minimization of residual thermal damage, and intraoperative hemostasis.

The CO₂ laser emits light at a wavelength of 10,600 nm. In this far infrared spectrum, most of the laser energy is absorbed by the superficial layers of skin (down to a depth of 30 μm). The thermal relaxation time of skin to this level is 200 to 600 μs. To minimize thermal damage, lasers have been developed with pulse durations shorter than 1 ms (1 ms = 1000 μs). The amount of energy needed to vaporize this thickness of tissue has been determined to be approximately 5 J/cm².

By rapidly heating the skin’s intracellular water, tissue is vaporized. Current CO₂ lasers vaporize tissue to a specific depth, with a single pass ablating 20 to 50 μm of skin. While different laser systems have been found to produce slightly varying degrees of residual thermal damage in the dermis, clinical effects have been similar. In general, increasing the number of laser passes correlates with increased depth of tissue penetration.

Most of the early complications of CO₂ lasers were related to the inability of the systems to provide sufficient high fluences to effect tissue vaporization. Instead, skin was charred, producing deeper tissue destruction than desired. The development of computerized scanning devices that deliver rapid, non-overlapping, uniform impacts has made the pulsed laser resurfacing procedure more efficient and effective. It is now possible to remove superficial layers of skin in a precisely controlled manner while minimizing unwanted thermal damage to tissue.

Despite the advances in laser technology, laser resurfacing is not a procedure without risk. Careful preoperative preparation and postoperative care is necessary when performing laser ablation. This review will highlight important features to consider for the preoperative evaluation and postoperative management of patients undergoing CO₂ laser resurfacing.

Patient Selection

Appropriate time should be dedicated to the initial consultation, as it is necessary to address several issues to determine whether or not a patient is a good candidate for cutaneous laser resurfacing. First, the patient’s expectations must be reviewed. Despite reports of clinical improvement averaging 80% in acne scars and 90% in facial rhytides, it must be stressed that resurfacing improves, but does not eliminate, all wrinkles and scars. Patients expecting perfection will be disappointed. The patient should be shown representative treatment photographs of similarly affected individuals, and realistic expectations must be emphasized.

In addition, the patient must be educated that the procedure is not entirely painless. In fact, full-face CO₂ laser resurfacing typically requires intravenous sedation and postoperative analgesics for optimal results. The use of these medications requires preoperative medical clearance to rule out significant cardiopulmonary disease. During the procedure, continual monitoring of the heart rate, blood pressure, and oxygenation is needed. In addition, a fully stocked emergency cart must be available, with staff trained in advanced cardiopulmonary resuscitation procedures in the event that a cardiopulmonary arrest occurs.

The patient must also be made aware that the postoperative course requires significant time away from work and other social engagements. It takes 7 to 14 days to re-epithelialize the skin, during which time...
patients experience varying degrees of edema, drainage, and burning discomfort within the laser-treated areas. Since a large wound is produced that will undergo healing by secondary intention, the patient must be willing to comply with rigorous postoperative wound care management.

Once expectations and compliance issues are established, appropriateness of lesions to be treated can be addressed. The cosmetic lesions most responsive to cutaneous laser resurfacing are those produced by chronic ultraviolet light exposure, such as “non-movement-associated” rhytides involving the periorbital, perioral, and cheek regions. Rhytides resulting from repetitive or excessive muscle activity (dynamic creases), such as the glabella furrows, crow’s feet, forehead creases, or nasolabial folds, may be improved, but results may not be as dramatic or long-standing because of unavoidable muscle activity. The use of botulism toxin for the treatment of these dynamic muscles (e.g., corrugators, lateral orbicularis oculi, and frontalis) can temporarily reduce the lines of expression, and is a significant advance as an adjuvant therapy for facial rejuvenation involving these areas. On the other hand, if the patient is concerned with pigmented irregularities, dramatic improvement may be obtained with superficial- and medium-depth peels.

Patients with Fitzpatrick skin types I and II are the best candidates for CO₂ laser resurfacing (Figure 1). Patients with skin type III develop temporary postinflammatory hyperpigmentation at an incidence ranging from 17 to 27%, whereas nearly all patients with type IV skin develop hyperpigmentation (Figure 2). Hyperpigmentation is initially noted within the first month following laser treatment and persists for 3 to 4 months. Because hyperpigmentation can worsen if the laser-treated area is exposed to sun, the patient must be compliant with sun avoidance for months after the resurfacing procedure.

A complete medical and drug history is important before any surgical procedure, including laser resurfacing. Certain risk factors for scarring may be obtained from the patient’s history. It is critical to obtain a recent history of isotretinoin use. Atypical scarring has been reported in a patient taking isotretinoin after dermabrasion. Although the incidence of this complication is not known, most laser surgeons find it prudent to wait at least 6 months, and up to 2 years after isotretinoin treatment, before considering laser resurfacing, and to avoid the use of isotretinoin for an equal period of time after resurfacing. Because patients with a history of hypertrophic scars or keloids are also at increased risk for postoperative scar development, this is considered a relative contraindication for laser resurfacing. If the patient is unsure of scar propensity, a test area can be lasered in the cosmetic unit under consideration.

Caution should be taken in pursuing resurfacing treatment in patients with a history of radiation therapy or scleroderma. Adnexal structures are diminished in these conditions, and because intact adnexae are necessary for successful re-epithelialization, significantly impaired wound healing would be expected. Patients with a prior history of radiation therapy have been shown to heal more slowly and experience more postoperative pain and erythema.

There are other medical conditions that render a patient a poor laser treatment candidate. Immunosuppressive conditions, such as acquired immunodeficiency...
ciency syndrome and prior organ transplantation, predispose the patient to impaired postoperative healing, as well as increased risk for postoperative infections. Koebnerizing conditions, such as psoriasis, verrucae, molluscum contagiosum, and vitiligo, could potentially worsen after laser resurfacing. Finally, inflammatory skin conditions such as acne should be under control before resurfacing. Inflamed acne cysts have been shown to marsupialize after dermabrasion, leading to worse scars than if they had been left alone. An anti-acne regimen should therefore be prescribed for those patients with acneiform lesions before resurfacing is performed.

Prior surgical history is also relevant. Skin that has recently been undermined, such as during a rhytidectomy, is characterized by diminished cutaneous circulation, and should therefore not be resurfaced for 3 to 6 months in order to avoid necrosis with resulting scarring. Moreover, because facelifting procedures often elevate the neck skin toward the mandible, care should be taken when resurfacing the area, as neck skin does not heal as well as facial skin due to its relative lack of pilosebaceous glands. Finally, patients with histories of prior lower blepharoplasties should be informed of the greater risk of ectropion formation due to the tissue-tightening effect of infraorbital skin after laser resurfacing.

Preparation for Resurfacing

With any resurfacing procedure, the possibility of infection must be discussed. Not only is there morbidity associated with the infection itself, but also, cutaneous infection could potentially lead to scarring. Multiple measures are taken to reduce the incidence of infection in the patient undergoing laser resurfacing, including prophylactic antivirals and antibiotics. The laser resurfacing procedure may stimulate herpes simplex reactivation. Initially, only patients with a history of cold sores were placed on antiviral medication. It was soon discovered, however, that even those patients with a negative history of herpes simplex could experience extensive, culture-positive herpes simplex virus infection of the resurfaced area.

Because a large percentage of the population has been exposed to herpes simplex, antiviral prophylaxis is now recommended to all patients undergoing resurfacing, regardless of personal history. Antiviral prophylaxis is typically initiated at least 24 hours before the procedure and continued for 10 days, at which time re-epithelialization should be complete. Acyclovir is generally prescribed at a dose of 400 mg orally three times daily. Famciclovir and valacyclovir have also been found to be effective for herpes prophylaxis. For patients with a strong history of herpes, a dose of 500 mg orally twice daily is recommended, whereas 250 mg orally twice daily is sufficient for those with no prior history of herpes (Figure 3).

Prophylactic antibiotics are typically used in conjunction with laser resurfacing, although no controlled studies evaluating their necessity have been performed. Commonly used antibiotics include dicloxacillin, azithromycin, and ciprofloxacin, all of which offer excellent coverage against gram-positive organisms such as Staphylococcus and Streptococcus. Even with antibiotic coverage, infections have been reported to occur in 1 to 4.3% of patients (Figure 4). Pathogens typically cultured include Staphylococcus...
FIGURE 5. Hyperpigmentation observed 1 month postoperatively and subsequently managed with topical glycolic acid, hydroquinone, and mild corticosteroids (to reduce irritative effects of topical therapy).

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*aureus* and *Pseudomonas aeruginosa*, the latter being most common in patients using a "closed" wound healing technique (described below). When infections are diagnosed early with prompt intervention, adverse sequelae (e.g., scarring) have been minimal.

The use of topical agents such as retinoic acid, alpha-hydroxy acids (e.g., glycolic acid), and hydroquinone in the preoperative period is not universal and remains controversial. Tretinoin is a proven therapy for photoaged skin, and has also been shown to enhance wound healing when used preoperatively for dermabrasion. Many physicians have extended its use to precondition the skin before laser resurfacing. Postoperative use of retinoic acid can also help maintain the benefits of laser resurfacing. Alpha-hydroxy acids are beneficial in the treatment of epidermal dyspigmentation and acne. Their use before and after resurfacing may help reduce postoperative pigmenitary irregularities and milia formation. Bleaching agents such as hydroquinone have routinely been prescribed to patients with skin type III and darker, in an attempt to decrease the incidence of hyperpigmentation following laser resurfacing. In a recent study evaluating the preoperative use of these agents, no significant difference was found in the incidence of post-CO₂ laser resurfacing hyperpigmentation in patients with skin types I to III who received pretreatment with either glycolic acid or combination tretinoin/hydroquinone, or those patients who received no pretreatment regimen. It was postulated that the re-epithelialized melanocytes originated from follicular units that were unaffected by topical pretreatment.

**Side Effects and Risks of CO₂ Laser Resurfacing**

Every patient will experience at least 1 week of significant morbidity after laser resurfacing until re-epithelialization takes place. Postoperative edema is universal and significant; eyes may be swollen nearly shut for 2 to 3 days. Treatment typically includes the continual use of ice packs, head elevation, and, for full-face procedures, a short postoperative course or intraoperative use of corticosteroids.

Controversy continues over the best postoperative regimen to care for the resultant exudative wound. From the burn literature, it is known that keratinocyte migration is impeded by crusting, thereby slowing the healing process, whereas moist wounds re-epithelialize more quickly. As semiocclusive ointments and hydrogel dressings both promote a moist healing environment, it remains unclear whether or not the wound should be left "open" (with ointment) or closed (with dressing). Open wound care consists of frequent soaking with cool water with or without a small amount of white vinegar (acetic acid). These cool compresses are applied frequently (e.g., hourly), in order to decrease serous exudate and to provide antibacterial properties. The skin is then coated with a healing ointment with few preservatives such as petrolatum or Aquaphor. The use of topical antibiotics (e.g., Polysporin, bacitracin) causes an unacceptable rate of contact dermatitis and has generally fallen out of favor. Wounds treated with petrolatum compared with those treated with a topical antibiotic have shown neither a higher infection rate nor longer healing time. Patients who use an open wound technique postoperatively are more involved in wound care management, but are benefited by cost savings (ointments are less expensive), and a decreased risk of infection.

In contrast, the use of an occlusive dressing in the immediate postoperative period leads to an increase in patient comfort and decreased patient involvement and anxiety. The dressing protects the wound, keeps in moisture, and in the case of hydrogels, absorbs exudate from the wound. A combined approach whereby a semiocclusive dressing is applied for a variable amount of time (e.g., 6 to 72 hours), followed by regular application of a healing ointment, has also been attempted. Obviously, the distinct advantages of each technique warrant further study in order to determine the best postoperative approach.

Acne and milia formation following laser resurfacing have been reported in upwards of 83.6% of patients. Possible explanations for their development have included the fact that lased skin becomes hypersebaceous, and that aberrant epithelialization with follicular plugging can occur with the use of thick emollients and occlusive dressings. The lesions are initially seen between the third and sixth week follow-
ing the procedure, often lasting 2 to 4 weeks. Treatment includes local extraction, retinoic acid, alpha-hydroxy acids, and oral antibiotics.2,3,4,5

Postoperative pigmentary alteration is common, with transient hyperpigmentation occurring in as many as 37% of patients.5,6 Patients with dark skin tones are particularly prone to its development as a result of increased epidermal melanin content.5,6 Hyperpigmentation is usually evident 1 to 3 months postoperatively,5,6 and generally resolves within 4 months.1,2,7,9,35,37 The incidence of hyperpigmentation can be decreased by limiting laser treatments to those patients with pale skin tones, treating darker skin phototypes more superficially, avoiding sun exposure, applying sunscreens, and using postoperative wound care that minimizes inflammation (avoiding infections and contact sensitivity).1,2 The topical pretreatment of skin does not appear to decrease the incidence of postoperative hyperpigmentation;6,7 however, postoperative use of sunscreens, hydroquinone, retinoic acid, and glycolic acid limits its severity and duration.6 (Figure 5).

Because postoperative hypopigmentation is a delayed phenomenon, occurring as late as 10 months postoperatively,7,35,37 it was not reported in the initial laser resurfacing studies with limited follow-up times.1,9 Hypopigmentation occurs in all skin types,1,8 but may be more noticeable in individuals with darker skin tones.9 Hypopigmentation is also more prominent in patients undergoing localized CO2 laser resurfacing.1,2,5,9 Hypopigmentation takes on special importance because, unlike hyperpigmentation, the loss of pigment appears to be permanent with no improvement, despite gradual ultraviolet light exposure.5

Post-treatment erythema is an expected outcome of laser resurfacing and is seen in all patients for weeks to months after resurfacing.1,9,35,37,51 Erythema persists for an average of 3 to 5 months postoperatively.5,35,37,51 (Figure 6). The clinical perception of erythema persists longer in patients receiving a localized treatment area compared with those undergoing full-face resurfacing.1,5,9,35,37 The amount of erythema is reportedly proportional to the degree of residual thermal damage in the dermis, with more prolonged and severe erythema resulting from deeper ablation.1,2,3,51 The intensity of erythema can vary depending on which laser system is used, but overall erythema duration after three passes using any CO2 resurfacing system with equivalent laser parameters is equal.1,9 It may be possible, but unlikely, that erythema can be reduced by avoiding tretonin use and by limiting rubbing with gauze intraoperatively.2,5 Postoperative erythema represents the effects of a combination of factors, including epidermal immaturity, reduced melanin absorption of light, reduced dermal optical scattering, and increased blood flow secondary to the surgically induced inflammatory response.5

Although prolonged erythema is an unfortunate side effect of laser resurfacing, it can be successfully camouflaged with makeup. The use of a yellow makeup base neutralizes the red color and results in immediate improvement, whereas a green makeup tint produces a “ghost-like,” unnatural appearance.24 The application of topical L-ascorbic acid in an aqueous formulation has proven to significantly decrease post-CO2 laser resurfacing erythema.54 The anti-inflammatory properties of vitamin C are believed to be responsible for the clinical effects. Topical vitamin C also has photoprotective qualities that make it a beneficial addition to the maintenance skin care regimen following CO2 laser resurfacing.5,24

Prolonged or excessive erythema may be due to superficial infection10 or contact dermatitis.2,2 A variety of soaps, moisturizers, topical antibiotics, topical diphenhydramine, vitamin E, sunscreens, cosmetics, and fragrances can lead to contact or irritant dermatitis and, thus, should be avoided in the immediate postoperative period. Once contact dermatitis is diagnosed, the offending agent must be eliminated and topical corticosteroids and oral antihistamines prescribed.1 It is important to note that pruritus is common for 2 to 4 weeks after resurfacing due to the normal re-epithelialization and wound healing process, and can be treated with low-potency topical corticosteroids.2

Prolonged erythema that cannot be explained by other factors, and its association with tissue induration, herald incipient scarring.10,2,25 Localized areas of temporary hypertrophic scarring have been reported to occur between 2 and 8 weeks postoperatively.1,2 Moreover, certain facial areas are prone to scar formation, such as the
philtrum, infraorbital, mandible, and neck.\textsuperscript{25,31,40} Extreme caution should be exercised when determining laser settings and number of laser passes in these areas.\textsuperscript{37}

Excess thermal damage is often caused by poor operator technique, including pulse or scan overlapping (stacking), incomplete removal of partially desiccated tissue between laser passes, and use of excessive energy densities.\textsuperscript{23,34,35} The appropriate number of passes depends on the treatment area, the laser used, and the laser parameters chosen.\textsuperscript{46} Since laser technique and clinical experience are essential elements to ensure successful treatment and reduce the risk of complications, apprenticeship work with an experienced laser surgeon is encouraged prior to performing the procedure independently.

If scarring occurs, expeditious treatment should be sought. Topical and intralosional corticosteroids and silicone gel sheeting are useful therapies.\textsuperscript{23,31,32} In addition, the 585-nm flashlamp-pumped pulsed-dye laser has proven to be an effective therapy in the clinical and symptomatic improvement of scars,\textsuperscript{31,35} presumably by its vascular-specific effect. An average of 2 to 3 pulsed-dye laser treatments at 6- to 8-week time intervals is typically needed to effect improvement in burn scars caused by CO\textsubscript{2} laser resurfacing.\textsuperscript{60}

Ectropion of the lower eyelid is a severe complication of laser resurfacing, observed most frequently in patients with a history of lower blepharoplasty and lax infraorbital skin. The condition rarely improves spontaneously, and thus requires surgical correction.\textsuperscript{37}

Summary
Cutaneous laser resurfacing is a tremendous advance in the treatment of photoaged skin. With the recent developments in laser technology, the procedure has become widely utilized among many physician subspecialists. The latest laser systems permit controlled vaporization of skin so that most novice operators feel comfortable with the technique in a short period of time. Nevertheless, there are many issues that need to be addressed before performing the procedure. First, not every person is an appropriate candidate for laser resurfacing. Second, both the physician and the patient must be aware of the preoperative preparation and prolonged postoperative care involved with the procedure. Finally, the physician must be able to identify and treat, and the patient must be educated about, the side effects and potential complications associated with the procedure. It is only by addressing these issues that the clinical results obtained by CO\textsubscript{2} laser resurfacing can be maximized.

REFERENCES
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