CARBON DIOXIDE LASER TREATMENT OF PEDAL VERRUCAE

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With the introduction of the ruby laser into medicine and surgery in the 1960s and the carbon dioxide (CO₂) laser into podiatric surgery in the 1970s, surgical lasers have revolutionized the way that practitioners treat various disorders. From its use for the excision of a multitude of skin lesions to surgical neurolysis and its impact on cartilage regeneration, the surgical laser is fast becoming not only "in vogue" as a treatment modality but state-of-the-art as well.

The CO₂ laser was developed by Patel in 1965 and is currently the most widely used and versatile laser in podiatric surgery. Through its photoablative properties, complete eradication of target lesions is accomplished easily. At the same time, surgical sterilization occurs in the area where the pathologic organisms are eradicated, decreasing contiguous spread. According to Lanzafame, the CO₂ laser is effective in the reduction of local tumor recurrence. Furthermore, a significant delay was discovered in the appearance of recurrent tumors in animals treated with the laser compared with animals treated with the scalpel. These favorable results occur due to the nontactile nature of laser surgery, the laser's destruction of cells and cell nuclei in the beam path, and its ability to seal small vessels and lymphatics in the course of operation.

Patients treated with the laser routinely relate less postoperative discomfort, swelling, and irritation than those treated with more conventional types of surgical methods. This is no doubt in large part due to the extreme accuracy of the laser and the subsequent decrease in adjacent tissue necrosis. Postoperative pain is diminished due to the sealing of nerve endings by the laser. At the same time, concurrent coagulation of vasculature and lymphatics resulting in a bloodless surgical field help contribute to a more favorable postoperative

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result. Although the CO₂ laser is the most used podiatric surgical laser, research into the various roles and effectiveness of the helium-neon (He-Ne), neodymium (Nd)-YAG, argon, erbium-YAG, excimer, copper vapor, and holmium-YAG lasers is currently underway. With respect to the field of podiatry itself, the CO₂ laser’s applications include the treatment of verrucae, onychocryptoses and onychomycoses, neuromas, skin lesions of all types, heel fissures, keloids, burns, ulcers, and venous abnormalities. In addition, the CO₂ laser currently is used in research to evaluate its capability to induce cartilage regeneration in laboratory animals.¹

LASER PHYSICS

Although laser physics is beyond the scope of this article, several basic relationships need to be addressed in order to give the reader insight into the various principles that pertain to laser use. The CO₂ laser beam wavelength is 10.6 µm, which places it into the invisible infrared electromagnetic spectrum. The He-Ne laser, therefore, is aligned coaxially with the CO₂ laser, because the former is visible and can act as a tracer for the CO₂ beam. Any matter containing water is then vaporized by the CO₂ laser as temperatures reach the heat of vaporization, or 100°C. Collagen, the primary protein comprising dermal skin, denatures at 65°C and shrinks when exposed to temperatures between 65°C and 99°C.² With an instantaneous rise in temperature to 100°C, the vaporization of water is completed, bypassing the denaturing stage. When temperatures reach in excess of 375°C, char is formed as tissue carbonizes. In the event that the lasering process is continued beyond the charring stage, a visible white flash of ultraviolet light, called carbon arcing, will occur as temperatures reach in excess of 4000°C. Carbon arcing should be avoided on account of detrimental tissue effects. Its ultraviolet emission also should be avoided due to possible ocular damage.

In maximizing the use of laser physics in surgery, several variables need to be well understood by the practitioner. These consist of power (expressed in W), spot size, beam type, distance, and time. Power is determined by the surgeon based on the type of surgical procedure being performed and by the area of the body being treated. Spot size (focal) is preset by the handpiece lens, but actual spot size is related to the distance between the handpiece and the tissue (focused compared with defocused). Time is proportional to contact between the beam and the tissue in question, and increases relative to the duration of exposure.

These variables, which are interrelated, help to determine the depth of penetration and subsequent tissue damage. As shown in Figure 1, the laser’s impact on tissue causes a centralized carbonization zone referred to as char, surrounded by zones of thermal necrosis and thermal effect. Superheated cellular debris constitute the carbonization zone, whereas the zone of thermal necrosis is comprised of nonviable material that has been coagulated. The outer zone of thermal effect contains viable cells that have been affected but not destroyed by the heat transmission.

CLASSIFICATION, HISTOLOGY, AND CLINICAL PRESENTATION

According to Cobb,² there are 55 specific genotypes of human papilloma-virus (HPV) and a correlation based on specific type and site. In dealing with
plantar verrucae, HPV types 1, 2, and 4 DNA are most often encountered. Histologically, all common verrucae share underlying characteristics—acanthosis, papillomatosis, and hyperkeratosis. Common warts (verruca vulgaris) are further differentiated from various other papillomas by the presence of vertically aligned parakeratotic cells, vacuolated cells, and areas of sequestered granules of keratohyalin.

Clinically, verruca vulgaris plantaris begins as an area of small, smooth papules that insidiously enlarge. Lesions are firm, and thrombosed capillaries almost always are visualized as small, pinpoint petechia upon debridement. Skin lines are interrupted by the lesions, and these growths are located most commonly over pressure-sensitive areas, such as the heels or metatarsal heads. Plantar verrucae tend to be endophytic, hence the actual size of a lesion that is clinically detected is much larger due to its involution and ingrowth within the dermis.

Periodically, multiple lesions may merge into what is termed a "mosaic wart" because of its clinical presentation. These lesions can be extensive and tend to be extremely recalcitrant due to the inherent presence of occult viruses,\(^8\) which are subepidermal viral channels that extend beyond the margins of the clinically visible lesions (Fig. 2). The authors propose that this extreme recalcitrance is due to the presence of both occult and latent papillomavirus\(^8\) in the result of immunoresponse. The clinician also should be aware of the existence...
of latent papillomavirus, i.e., dormant viral particles that coexist within normal tissue areas as well as beyond visible verrucous margins. In dealing with verrucae that most commonly involve the extremites, HPV types 1 and 2 DNA are encountered most frequently. Direct exposure, whether it is person-to-person, airborne, or fomite, may act as a mode of transmission anywhere on the body.

**TREATMENT**

Treatment of plantar verrucae is initiated for several reasons: (1) to prevent subsequent spread to contiguous locations; (2) to alleviate pain caused by the lesion that is present under a weight-bearing or pressure-sensitive area; and (3) to improve cosmesis. The successful diagnosis and treatment of verrucae is something that has bedevilled the medical practitioner ever since the time when witchcraft was employed to ward off the lesion. Because no treatment or remedy has ever shown itself to be 100% effective in eradicating the virus, many modalities have been used to achieve this end. The results have ranged from a cure rate of 32.2% using intralosomal bleomycin sulfate, 61% using salicylic acid, 65% using electrocautery, 81% using monochloracetic acid, to 91% using cryosurgery. The authors have found a 93% overall success rate in the treatment of solitary lesions with the CO₂ laser technique. These various methods used for the elimination of verrucae have yielded varying success rates depending upon the individual researcher and treatment methodology applied. CO₂ laser vaporization of verrucae, however, continually has yielded success rates in the 90th percentile and higher.

Other techniques, such as intralosomal recombinant α-2 interferon, other keratolytics, and blunt curettage are available but have produced only limited success. Even placebos have been used with a 27% rate of success. With such a wide variation in both treatment methods and outcomes, pediatric surgeons have sought effective means for treating these stubborn lesions. As previously
mentioned, one such method is the use of the CO₂ laser for ablation and excision of plantar verruca. According to Mancuso and colleagues, the CO₂ laser constitutes a viable treatment option for this condition, producing an overall success rate of 93% for solitary isolated lesions that were untreated previously, a 74% ultimate success rate for solitary lesions that were treated previously, a 70% success rate for multiple isolated verrucae that were treated previously, and a 62% success rate for multiple verrucae that were treated previously. The overall success rate for every type and classification of verruca was 75% regardless of previous treatment modalities used. This study was unique in its design and presentation in the fact that it emphasized the classification and differentiation of various verrucous manifestations along with their respective treatment success rates.

SURGICAL TECHNIQUE

In dealing with the use of the CO₂ laser for the excision and ablation of plantar verrucae, a stringent protocol was set up by the authors. Local anesthesia was used at the site of the lesion, with a 50/50 mixture of 0.5% bupivacaine and 1% lidocaine, with epinephrine 1:100,000 infiltrated subcutaneously. The verrucous lesion then was debrided superficially and a specimen was taken and sent for microscopic evaluation. Because verrucae can be diagnosed clinically by the physician (cessation of skin lines, pain to lateral compression, micropetichiae), a preoperative pathologic confirmation was not necessary. No sterile preparation was performed prior to the procedure. Once the superficial layers were debrided, the peripheral boundaries of the lesion were identified, with care being taken to visualize any small areas of verrucous tissue that may have been present but had been undetected previously due to overlying hyperkeratosis.

In keeping with the Centers for Disease Control’s Universal Precautions Policy, the physician dons surgical gloves and a barrier (Johnson & Johnson, New Brunswick, N.J.) laser plume face mask capable of filtration down to 0.1 μm. A Stackhouse (Stackhouse, Inc., Riverside, CA) laser smoke filtration system was also used along with a 0.2 μm in-line viral filter to enhance filtration. The CO₂ laser was then set at a power setting of approximately 7 to 10 W on a continuous mode with a power density upwards of 1000 W/cm². Wattage was set in accordance with the depth of the lesion as well as the area at which it was located. Because the CO₂ laser beam itself is invisible, guidance was achieved through a He-Ne laser beam that appears red and, as previously described, is aligned coaxially to afford exact localization of the CO₂ laser beam.

At a distance of 2 to 2.5 cm, focusing of the focal spot is possible. When dealing with a large lesion, the authors tend to use pinpoint laser bursts at the periphery of the lesion and then connect these areas in a circumferential motion (Fig. 3A). Care always was taken to use the laser outside the boundary of the visualized lesion in order to increase the chance of ablating any occult or latent verrucae that may have been present. This distance was variable but tended to be approximately 3 to 4 mm larger in circumference than the actual lesion. Vaporization then was carried out with transverse sweeping motions within the confines of the previously outlined lesion (Fig. 3B). Layer by layer, the verrucae was ablated. The epidermal layers were removed at the dermal-epidermal junction where heat penetration causes a natural liquefaction to occur, whereby differentiation and subsequent separation of the juncture is facilitated. The resultant residual char was wiped off with a firm motion using
saline-soaked gauze (Fig. 3C). Care was taken not to use alcohol or any other flammable solution for flushing the area because of the possible risk of combustion if the solution and laser interact.

Char was removed because it has the ability to absorb energy and, thus, may generate excessive heat. Relasering char also can affect the accuracy of the procedure possibly by causing heat dissipation into deeper layers. Decreased visualization from the presence of char may cause obliteration of dermal skin. Char, therefore, was removed bluntly after each pass of the laser.

The lesion area was examined constantly for verrucae, and the same procedure was carried out from layer to layer. Any vessels that were encountered were coagulated using a defocused beam with a lower power density that causes coagulation but not vaporization. Differentiation was noted and appreciated with respect to how the laser affected verrucous as opposed to normal tissue. Verrucous tissue responded to the laser by exhibiting a bubbling effect (Fig. 4), whereas normal tissue shrank due to collagen denaturalization. Certain lesions extend into the papillary and reticular dermal regions (Fig. 5), and thus ablation to this tissue depth for these lesions is mandated. According
to Lemont and Parekh, light microscopy of verrucae excised from the foot exhibit tongues of hyperplastic epidermis extending to the reticular dermis. It is necessary, therefore, to exceed the laser's penetration to the level of the superficial fascia. Even though the typical level is dermal-epidermal, penetration never exceeded the level of the superficial fascia, which was easily determined by the presence of a glistening layer deep to the reticular dermis. Penetration of this layer would result in herniation of adipose tissue into the wound.

Once the presence of verrucous tissue could no longer be confirmed, the surgical site was flushed again to remove any remaining char and inspected for hemorrhage. If bleeding or oozing were present, then the laser was used again in an unfocused manner, whereby coagulation was attained. Further denaturation of collagen occurred and the wound contracted. The site was flushed carefully so as not to disturb any vessels that may have clotted. A thin layer of Cortisporin ointment (Burroughs Wellcome Co., Research Triangle Park, NC) then was applied, followed by packing with Gelfoam (Upjohn Co.,

Figure 4. Bubbling effect of verrucous tissue upon CO₂ laser ablation.

Figure 5. Lesion extending into the papillary and reticular dermal regions.
Kalamazoo, MI) and another layer of Cortisporin ointment (Fig. 6). Then, a dry, sterile compression dressing was placed over the surgical area.

The patient was instructed to leave the postoperative bandage in place for 24 hours, taking care not to wet the area. Postoperative instructions were reviewed with the patient, which included a prescription of Cortisporin ointment to be applied twice daily. Cortisporin ointment was favored by the authors because of its inherent anti-inflammatory and antibiotic properties. The use of the laser itself helps to minimize the body's anti-inflammatory response because heat is lost as vapor and is dissipated to cells already vaporized, so that peripheral tissue is inflamed only minimally. Thus healing time and postoperative pain are diminished by minimizing the inflammatory and healing processes. Bathing was allowed following the initial 24-hour period. No narcotic pain reliever was prescribed, but the patient was advised to take ibuprofen as needed. Cotton bandages were used to cover the area daily.

Patients were followed up on an ongoing basis starting 1 week following the date of surgery and then every 2 or 3 weeks thereafter until healing was complete. The granulation process by which the surgical wound heals occurs from deep to superficial, and sometimes took up to 6 weeks depending on the lesion size. Antibiotic ointment was applied twice daily until the time of eventual healing. It should be noted that, although a surgical wound is present, the area is usually not symptomatic after the first 24 to 48 hours. The granulating wound often looks “worse than it feels” and may sometimes give the appearance of a fulminating infective process to the untrained or inexperienced eye because it appears with drainage, erythema, edema, and sensitivity. These

Figure 6. (A) Immediate postoperative view of lesion. (B) Application of polymyxin B sulfate, bacitracin zinc, neomycin sulfate, hydrocortisone (Cortisporin ointment). (C) Application of Gelbain (Upjohn Co., Kalamazoo, MI). (D) Dry, cotton dressing applied.
signs are usually associated with a burn rather than an infection. The authors claim that these surgical wounds may be superficially contaminated but are not infected.

**COMPPLICATIONS**

As with any surgical procedure, the risk of perioperative complications is always a possibility. Using proper techniques and adhering to strict surgical principles help to minimize the potential risk of complications, although the inherent risk is always present. According to the study conducted by Mancuso and colleagues, the most common complication encountered with CO₂ laser ablation of verrucae was the formation of asymptomatic scar tissue at the surgical site, followed by hyperkeratotic scar tissue, sterile abscess, excessive hemorrhage, and soft tissue infection requiring antibiotics. Other complications included osteomyelitis, epidermal inclusion cysts, and excessive drainage.

Scar tissue forms during the healing process. Whether scar tissue proves to be symptomatic or not is related to the depth of penetration, piezoelectric potentials, and the site of the lesion. Normally, the surgeon endeavors to avoid penetrating the superficial fascia, which is the layer separating cutaneous and subcutaneous tissue. Penetration of this layer may increase the risk of developing scar tissue formation. Piezoelectric potentials help to decrease the risks of developing hypertrophic scar tissue because increased pressure from weight-bearing allows orderly reformation of collagen fibers. According to Forrester and colleagues, Wolff's law is applicable to connective tissue. This can be extrapolated to show how force, stress, and motion direct collagen fiber and proteoglycan alignment. In light of this, weight-bearing without dispersion padding is encouraged. This is in contradistinction to dorsal lesions, where no weight-bearing occurs and where scarring tends to be more severe.

Recurrence of the lesion also was experienced, although when a lesion did recur, it commonly did so at the periphery, most probably due to an occult or latent virus. According to Ferenczy and colleagues, the presence of latent papillomavirus has been demonstrated at 5, 10, and 15 mm distances from the visualized verruca. It is for this reason that many researchers routinely use the laser's ablative properties at a distance of at least 3 to 4 mm wider than the lesion. Even adhering to these guidelines, however, does not completely prevent the formation of virulent particles at the peripheral margins of the verruca. Obviously, the presence of viral material at the periphery is something that needs to be addressed. It is impractical, however, to use a margin wider than approximately 3 to 4 mm because of the increased trauma and size of the resultant surgical defect. The authors currently use 5-fluorouracil, an antineoplastic metabolite that interferes with DNA and, to a lesser extent, RNA synthesis in order to help decrease recurrences and improve success rates.

In discussing complications of CO₂ laser surgery, the effect the laser plume has on eventual outcomes must be mentioned. The viability of cellular particulate matter within the plume has been documented and may be an important factor in recurrence. The virus also has been shown to lack an envelope, thereby making it resistant to inactivation, freezing, and desiccation. The plume may not represent a significant risk of reinfection to the patient, however, because of chronic exposure already occurring, but it can pose a risk to the surgeon through primary exposure. In any case, the surgeon must be wary of the plume and take appropriate precautions, including the use of gloves, masks, and a smoke evacuator. The latter, if held at approximately 1 cm from
the surgical site, can be approximately 99% effective in filtering out debris from the plume and only 50% effective if the distance is increased to 2 cm.18

SUMMARY

Physicians always are pursuing improved results. In the case of pedal verrucae, the varying treatment modalities that have evolved are the product of a search, so far less than successful, for one that is virtually 100% effective. HPV is an extremely resilient and elusive organism, possessing the capabilities of lying dormant and suddenly springing to the surface of the skin. Although no single treatment modality has been shown to be a panacea, the authors believe that, among the various treatment alternatives available, the CO2 laser offers the best surgical prospect for eliminating the verruca and minimizing the sequelae of recurrence and postoperative pain.

References


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