SMALL ANIMALS

Histologic comparison of skin biopsy specimens collected by use of carbon dioxide or 810-nm diode lasers from dogs

Lillian B. Rizzo, DVM; Jerry W. Ritchey, DVM, PhD, DACVP; Russell G. Higbee, PhD, DVM; Kenneth E. Bartels, DVM, MS; Michael D. Lucroy, DVM, MS, DACVIM

Objective—To compare histologic artifacts caused by carbon dioxide (CO_2) or 810-nm diode surgical lasers used to obtain small biopsy specimens of skin from healthy dogs.

Design—Prospective study.

Animals—4 dogs.

Procedure—21 skin biopsy specimens were collected from each dog. Three biopsy specimens were obtained with a CO_2 or an 810-nm diode laser at 3 operating settings each, and 3 biopsy specimens were obtained with a 6-mm biopsy punch instrument (controls). After processing, biopsy specimens were examined for artifacts related to laser-tissue interactions. Microscopically visible char was measured from the lateral edge of each specimen obtained with a laser.

Results—There were no significant differences among mean char distances in biopsy specimens obtained with the CO_2 laser at various settings. Mean char distance was significantly greater in all skin biopsy specimens obtained with the diode laser, compared with those obtained with the CO_2 laser. Mean char distance was significantly greater in biopsy specimens obtained with the 810-nm diode laser at high power, compared with biopsy specimens obtained with the 810-nm diode laser at low power.

Conclusions and Clinical Relevance—Results indicated that the CO_2 laser caused less thermal injury at margins of skin biopsy specimens; therefore, if a surgical laser is used for removal of cutaneous masses or to obtain skin biopsy specimens, use of the CO_2 laser is recommended. Veterinarians performing a biopsy by using a surgical laser should be aware that laser-induced artifacts may render small biopsy specimens useless for providing accurate histologic diagnosis. (*J Am Vet Med Assoc* 2004;225:1562–1566)

Laser technology has been aggressively marketed to veterinarians during the past decade. Surgical lasers are presently in use at many veterinary teaching institutions and an increasing number of private veterinary practices. These lasers are described in terms of their lasing medium and wavelength. The lasing medium may be gas, liquid, solid crystal, or a laser diode. A gas laser commonly used for veterinary surgical applications is the **carbon dioxide (CO_2)** laser. The CO_2 laser generates a wavelength of 10,600 nm in the far infrared region.[1-6] Carbon dioxide laser energy is delivered to tissues through a hollow waveguide or an articulating arm. The 10,600-nm light is highly absorbed by water. Because 98% of the laser energy is absorbed within 0.01 mm of tissue, thermal transmission to surrounding structures is minimal.[7] Reported thermal damage to surrounding tissue varies from < 0.1[8-10] to 0.5 mm.[11] The CO_2 laser is primarily used as a surgical scalpel. With different power settings and beam diameters affecting power density, the CO_2 laser is capable of heating, cutting, or vaporizing surfaces and sealing small blood vessels.[7]

Semiconductor diode lasers are also presently used for veterinary surgical applications.[1,12,13] Medically useful diode lasers are gallium aluminum arsenide and indium aluminum arsenide,[14] operating at near infrared wavelengths of 810 or 980 nm, respectively.[12,13] Quartz optical fibers deliver the laser energy to the tissue in either contact or noncontact modes and permit these lasers to be used with flexible endoscopy equipment. Depending on the power density, the fibers are capable of incision, vaporization, ablation, or coagulation of soft tissues.[12,13] Contact mode diode laser surgery is used for tissue incision. When used in contact mode, the diode laser can make a precise incision; however, collateral thermal damage may extend > 0.5 cm into the surrounding tissue.[1]

Although surgical lasers are being used with increasing frequency by veterinarians, there are few data about laser-tissue interactions in domestic animal species. Much of the early available information about laser-tissue interactions is derived from human, rodent, or cadaveric tissues. Given the ability of flowing blood to dissipate laser-generated heat (thermal relaxation), these models may not be applicable to companion animals. This may be especially important in the skin where the blood supply is known to vary among species.

One potential use for surgical lasers is the resection or biopsy of cutaneous masses. Because of the excellent hemostasis and decreased pain and minimal swelling postoperatively, the laser is an attractive option, compared with the scalpel blade. However, to the authors' knowledge, there are no reports in the veterinary literature describing the effects of surgical laser energy on small biopsy specimens.

From the Departments of Veterinary Clinical Sciences (Rizzo, Higbee, Bartels, Lucroy) and Veterinary Pathobiology (Ritchey), College of Veterinary Medicine, Oklahoma State University, Stillwater, OK 74078. Dr. Rizzo's present address is Sonora Veterinary Specialists, 13442 N 50th St, Scottsdale, AZ 85254. Dr. Higbee's present address is Sciperio Incorporated, 5202-2 N Richmond Hill Rd, Stillwater, OK 74075. Dr. Lucroy's present address is Department of Veterinary Clinical Sciences, School of Veterinary Medicine, Purdue University, West Lafayette, IN 47907.

Supported in part by the Kerr Foundation Incorporated.

Address correspondence to Dr. Lucroy.

In humans, the histologic reliability of laser biopsy specimens has become an area of concern since laser conization of the cervix has been advocated as the treatment of choice for cervical intraepithelial neoplasia. Laser conization is preferred to ablative techniques because it provides a specimen for histologic diagnosis with minimal short- and long-term complications. Cure rates of 87% to 98% are possible provided proper selection of patients on the basis of accurate histologic findings.[15] Results of studies[15,16] of cervical biopsy specimens in women comparing histologic reliability with various collection methods indicate that the CO_2 laser used at various settings and operating modes generates coagulation artifact, making recognition of CIN extremely difficult or impossible and assessment of margins extremely difficult or impossible in 27% of the specimens. This may also be true in veterinary medicine. Results of a study[17] indicate that carbonization was invariably present in specimens obtained by use of CO_2 lasers, preventing histologic evaluation. However, results of another similar study[18] reported that the thermal zones of injury caused by CO_2 lasers made no substantial impact on the interpretation of margin adequacy. Results of 1 study[19] comparing the CO_2 and **neodymium:yttrium-aluminum-garnet (Nd:YAG)** lasers indicate that the CO_2 and Nd:YAG lasers both caused considerable char and artifact.

Because the collateral thermal damage that occurs in the patient's tissue resulting in delayed wound healing and wound dehiscence also affects the tissue of the biopsy specimen, laser-induced artifacts may render small biopsy specimens useless for providing a pathologic diagnosis. Therefore, the purpose of the study reported here was to compare histologic artifacts caused by CO_2 or 810-nm diode surgical lasers used to obtain small biopsy specimens of skin from healthy dogs.

Materials and Methods

Dogs—Four healthy, purpose-bred, mixed-breed dogs were used for this study. Biopsy specimens of skin were collected from dogs during general anesthesia. This study was approved by the Oklahoma State University Animal Care and Use Committee.

Surgical procedures—The skin overlying the lateral thorax was clipped and aseptically prepared. Full-thickness skin biopsy specimens were obtained from the lateral thorax of each dog with a CO_2 laser,[a] an 810-nm diode laser,[b] or a 6-mm biopsy punch. Biopsy sites were spaced ≥ 3 cm apart. Three biopsy specimens were obtained from each dog with each laser at 3 operating settings. Three control punch biopsy specimens of skin were also obtained from each dog. Personnel in the surgery room wore laser safety glasses protective for 810- and 10,600-nm wavelengths and laser-safe, hydrophobic surgical masks.[c] The laser plume generated during the biopsy procedures was removed with a high-efficiency particulate air-filtered smoke evacuation device.[d]

Power output from each laser was calibrated before the biopsy procedures were performed. The laser beam was oriented perpendicular to the skin surface, and tension was applied to the skin by the surgeon's free hand. The circular biopsy specimens were approximately 6 mm in diameter to attempt to simulate the shape and size of the control specimens. Thumb forceps were used to manipulate the biopsy specimen as it was cut free with the laser from surrounding tissues. All laser biopsy procedures were performed by a single investigator (LBR). The CO_2 laser energy was launched into a hollow waveguide terminating in a 0.8-mm ceramic tip.[e] The tip was changed between each dog. With the CO_2 laser operating in superpulse mode and the ceramic tip positioned between 1 and 2 mm from the skin surface, biopsy specimens were obtained with 10 W of energy output. With the CO_2 laser operating in continuous wave mode and the ceramic tip positioned between 1 and 2 mm from the skin surface, biopsy specimens were obtained with 10 or 20 W of energy output. The resultant power densities (W/cm^2) were 2,000 W/cm^2 for 10 W of energy output and 4,000 W/cm^2 for 20 W of energy output.

The 810-nm diode laser energy was launched into a 1-mm-diameter quartz optical fiber terminating in a cleaved tip.[f] With the 810-nm diode laser operating in continuous wave mode and the tip in direct contact with the tissue, biopsy specimens were obtained with 10 W (low), 20 W (medium), and 40 W (high) power output. These resultant power densities (W/cm^2) were 1,250 W/cm^2 for low-power output, 2,500 W/cm^2 for medium-power output, and 5,000 W/cm^2 for high-power output. Microscopically visible char was measured from the lateral edge of each circular biopsy specimen, and the means were reported for each operating parameter with each laser.

Histologic procedures—All tissue specimens were placed directly into neutral-buffered 10% formalin and routinely processed, embedded in paraffin, sectioned at 5 µm, and stained with H&E stain. Sections were examined and the depths of the laser-induced artifacts (char and coagulation necrosis) were measured by use of a calibrated reticle eyepiece. Char is characterized as a complete loss of tissue architecture with replacement by deeply basophilic, acellular, amorphous material. With coagulation necrosis, the outline or detail of tissue architecture is present; however, the extracellular matrix (collagen) is pale basophilic, and resident cell populations are either absent or have signs of necrosis.

Statistical analyses—Quantitative variables were compared among groups by use of 1-way ANOVA and the Tukey-Kramer post hoc test. Values of $P < 0.05$ were considered significant. Statistical analyses were performed with computer software.[g] All values are reported as mean ± SD unless otherwise indicated.

Results

Mean char distance was significantly ($P < 0.05$) greater in all skin specimens obtained with the diode laser, compared with those obtained with the CO_2 laser. There were no significant differences among mean char distances in biopsy specimens obtained with the CO_2 laser at the various settings. Mean char distance was significantly ($P = 0.002$) greater in biopsy specimens obtained with the 810-nm diode laser at high power, compared with biopsy specimens obtained with the 810-nm diode laser at low power (**Table 1**).

Tissues obtained with the CO_2 laser had a uniform char that was restricted to the peripheral margin of the biopsy tissue only (**Figure 1**). There was an abrupt demarcation between the char and underlying viable tissue, with little to no intervening zone of coagulation necrosis. In contrast, sections obtained with the 810-nm diode laser had marked peripheral charring underlain by coagulation necrosis, the severity of which was directly proportional to the power intensity level of the instrument. Under low settings, the center portion of the tissue was spared damage; however, under high-power settings, the architecture of the entire sample was effaced by either char or coagulation necrosis. There was no degree of crush or handling artifact histologically identified in any of the control biopsy specimens.

Table 1—Mean ± SD char distance in biopsy specimens from healthy dogs obtained with a carbon dioxide (CO_2) laser and an 810-nm diode laser at 3 operating parameters.

Laser setting	CO_2 laser char distance (mm)
10 W SP	0.34 ± 0.191
10 W CW	0.31 ± 0.092
20 W CW	0.41 ± 0.144
Relative laser power	**Diode laser char distance (mm)**
Low	3.77 ± 1.68
Medium	4.86 ± 1.71
High	6.02 ± 1.62*

*Significantly ($P = 0.05$) different from the low value for the diode laser.
SP = Super-pulse mode. CW = Continuous wave mode.

With the CO_2 laser set at super-pulse mode and 10 W of power, approximately 12% of the biopsy specimen was affected by the laser energy, resulting in char formation. With the CO_2 laser set at continuous wave mode with 10 and 20 W of power, approximately 11% and 14%, respectively, of the biopsy specimen was affected by the laser energy. For the 810-nm diode laser set on low power, 7 of 12 biopsy specimens were 100% affected by char. Of the remaining 5 biopsy specimens, approximately 64% of the biopsy specimen was affected by char. With the diode laser at the medium- and high-power setting, 100% of the specimen was charred by the laser energy in all biopsy specimens.

Hemorrhage was observed while obtaining the control biopsy specimens with the 6-mm punch; however, this hemorrhage was minimal. No hemorrhage was observed while obtaining the biopsy specimens using the CO_2 or diode laser.

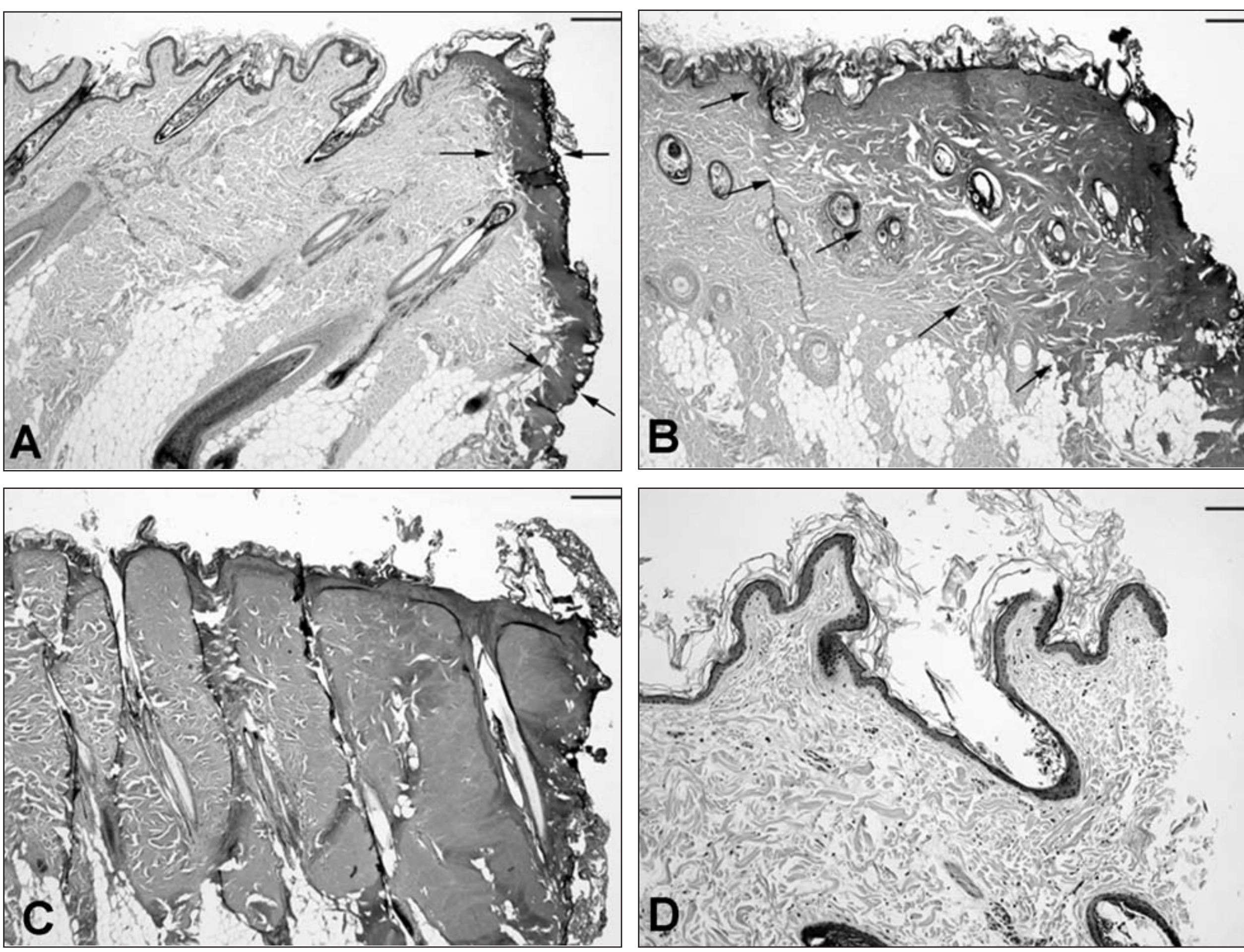

Figure 1—Photomicrographs of representative sections of biopsy specimens of skin from healthy dogs obtained with carbon dioxide (CO_2) and 810-nm diode lasers. A—The CO_2 laser causes a uniform zone of carbonization (region between arrows) that is abruptly demarcated from otherwise normal underlying tissue. B—The 810-nm diode laser causes peripheral carbonization overlying varying depths of coagulation necrosis. Under low operating settings, tissue in the center portion of the biopsy specimen is spared (tissue to the left of the arrows). C—Use of the 810-nm diode laser under high operating settings causes the tissue architecture to be effaced by either carbonization or coagulation. D—Skin biopsy specimen obtained with a 0.6-mm biopsy punch instrument (control). H&E stain; bar = 220 µm.

Discussion

Mean char distance was significantly greater in all skin biopsy specimens obtained with the 810-nm diode laser, compared with those obtained with the CO_2 laser. This result was expected because the wavelength of the diode laser is primarily absorbed by melanin and hemoglobin that may not be present on the surface of the skin, permitting the energy to penetrate deeper into tissue than the CO_2 laser.[12] The high water absorption coefficient of the CO_2 laser wavelength combined with the water content of tissue may make this the preferred laser for general soft tissue surgery.[20,21]

Mean char distance was significantly greater in specimens obtained with the 810-nm diode laser at high power, compared with specimens obtained with the 810-nm diode laser at low power. This result was also expected because it is generally suggested that energy settings < 20 W are adequate for contact laser applications with the diode laser.[12] The higher the power setting, the quicker and easier it was to create the incision. Therefore, it is tempting to increase the power to shorten and ease the procedure. In the study reported here, the mean char distance was similar to that previously reported.[1]

For the CO_2 laser, the super-pulsed mode and continuous wave mode at 10 W of power did not cause different amounts of char between the biopsy specimens. This is an unexpected observation. Charring occurs when tissue absorbs heat faster than it can be dissipated by either circulating blood or conduction through the tissue. When the CO_2 laser operates in super-pulse mode, each laser pulse has high energy (> 5 J/cm^2) of short duration (< 10^{-3} seconds), thereby reducing the energy delivered to tissue, theoretically minimizing the potential for charring.[10,22-24] The interval between each pulse is longer than the tissue thermal relaxation time. This minimizes thermal damage to surrounding tissue.

Biopsy specimens obtained with the CO_2 laser set at 10 and 20 W did not have significantly different amounts of char. This suggests that 20 W of CO_2 laser energy is less than the temperature threshold predicted by the kinetic damage model.[10] Although there was a greater distance of char present in the high-power group, the difference was not significant. In our study, the amount of char observed was consistent with that described elsewhere.[8-11]

A surgeon using a CO_2 laser could use a 0.3- or 0.4-mm tip to increase power density and precision while decreasing collateral photothermal change. Other types of CO_2 lasers with articulating arms and focused laser beams of 0.125 mm could also increase precision, compared with the 0.8-mm tip used in this study. In addition, most surgeons performing incisional soft tissue procedures with a CO_2 laser do not use the 0.8-mm tip; however, in this study, we were comparing the beam diameter from a 0.8-mm tip with the 1-mm quartz tip used with the 810-nm diode laser available for this study. A diode laser used in contact mode could be used with a 400- or 600-µm fiber with either a cleaved or a sculptured tip to increase precision and decrease collateral photothermal injury.

Previous studies comparing different laser types and surgical techniques have focused mainly on healing characteristics of various tissue types. Animal models have been used for many of those studies; however, to the authors' knowledge, there are no studies in the veterinary literature reporting acute thermal injury to tissue following laser surgery. One study[25] histologically examined the soft palate in dogs following resection with the CO_2, contact Nd:YAG, or combined CO_2 and contact Nd:YAG laser beams. The CO_2 laser was used with a mean power output of 32 W in super-pulse mode. Results of that study indicate that there were no significant differences in amounts and depths of thermal tissue damage between the 3 laser modalities. The depth of thermal tissue damage was measured microscopically by use of high-power fields. Results of another study[26] assessing delays in wound healing in the skin of rats caused by the CO_2 laser indicate that acute thermal injury was detected following incisions with the laser set at 5-W continuous wave and various pulsed settings. Acute thermal damage measured in the continuous wave mode was 0.33 mm, which is consistent with results of other studies.[27-29] The pulsed laser caused a mean thermal damage distance of 0.118 mm when used at the 5-Hz pulse repetition rate. This was higher than results of a similar study[24] with guinea pig skin, in which 50-µm of thermal damage was detected with a 2-microsecond pulsed CO_2 laser. The few other reports[30-32] that used dog skin and the CO_2 laser only assessed wound healing, and 1 other study[33] assessed healing of buccal incisions in dogs. The lack of data relating to CO_2 laser use in skin of dogs poses potential diagnostic pitfalls when attempting to use the laser for incisional or excisional biopsy of cutaneous masses.

Tissues obtained with the CO_2 laser had minimal tissue damage that would not be expected to interfere with diagnostic evaluation. In contrast, tissues obtained with the diode laser were mostly suboptimal (at low settings) to useless (at high settings) for diagnostic evaluation secondary to the level of thermal injury of the tissue. Results of our study indicated a zone of thermal damage of 0.31 to 0.41 mm for the CO_2 laser and 3.77 to 6.02 mm for the 810-nm diode laser. If a surgical laser is preferred for removal of cutaneous masses or to obtain skin biopsy specimens, use of the CO_2 laser rather than the 810-nm diode laser is recommended because of the amounts of thermal injury obtained with each method. The diode laser caused excessive amounts of thermal injury at the margins regardless of power setting. The CO_2 laser caused 0.31 mm of thermal injury when used at 10 W of power in a super-pulse mode, 0.34 mm of thermal injury when used at 10 W of power in a continuous wave mode, and 0.41 mm of thermal injury at the margin of the sample when used at 20 W of power in a continuous wave mode. Therefore, it is important to maintain appropriate distance away from the tissue of interest on the basis of the CO_2 laser setting used, the power density attained, and the char distance reported in this study. The ideal specimen should not have any thermal artifact that would interfere with interpretation of completeness of excision. A delay in or lack of diagnosis may lead to an unnecessary delay in appropriate treatment.

Advantages of using the CO_2 laser rather than a scalpel for cutaneous mass removal relate primarily to the benefits of decreased hemorrhage with the laser. However, use of the CO_2 laser may prove to be an unsuitable technique when a reliable histologic diagnosis is required. Clinicians should be aware that if a laser is used to obtain biopsy specimens, a portion of the biopsy specimen cannot be used for histologic evaluation. However, if adequate margins around the tissue of interest are respected, then the CO_2 laser can be a useful tool.

[a]Luxar Nova Pulse 20 watt CO_2 laser, Model #LX-20 SP, Luxar Corp, Bothell, Wash. (Presently available as AccuVet, Lumenis Inc, Santa Clara, Calif.)

[b]Diomed 60 Limited, Diomed Inc, Andover, Mass.

[c]Tecnol lazer surgical mask, Centre d' Affaire Actimart, Aix En Provence Cedex 03, France.

[d]Luxar AirSafe smoke filtration system, Luxar Corp, Bothell, Wash. (Presently available as AccuVet, Lumenis Inc, Santa Clara, Calif.)

[e]Luxar 0.8-mm ceramic tip, Luxar Corp, Bothell, Wash. (Presently available as AccuVet, Lumenis Inc, Santa Clara, Calif.)

[f]Diomedics 1-mm quartz optical fiber, Woodlands, Tex.

[g]SigmaStat, version 3.0, SPSS Inc, Chicago, Ill.

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