CO₂ Laser Surgery - Turn it on, Turn it up
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CO₂ Laser Surgery - The Basics

CO₂ lasers are a popular tool in the hands of veterinary surgeons. Practices have incorporated CO₂ lasers into their surgical protocols with positive effects on their patients, on client perception of quality of care, and on practice image. They have done so in ways that have made CO₂ laser technology affordable and profitable.

Virtually every soft tissue surgery can be adapted to include the use of CO₂ laser technology. Through their effect on tissue, CO₂ lasers reduce hemorrhage, reduce blood loss, and allow the surgeon to work in a clear field. They reduce post-operative swelling and pain. In addition, they allow surgeons to do procedures requiring very precise removal of tissue.

The Science of the Light Scalpel

CO₂ lasers emit an invisible laser beam in the far-infrared spectrum, at 10,600 nm. They have become the soft tissue surgical laser of choice because of how that wavelength of light interacts with tissue.

The photonic energy in 10,600 nm laser light is absorbed by water. The energy is converted into heat, cells are ruptured, and tissue is vaporized. Most of the energy delivered to the tissue is released in a vapor or steam plume. Despite delivering high amounts of energy into a small area of tissue, this photo-thermal interaction creates minimal change in the tissue left behind.

When properly used, a CO₂ laser creates a minimal zone of collateral thermal change in the tissue. Correct technique and laser settings can result in as little as 100 microns of the tissue being affected by the high-energy delivery. This zone of reversible change produces the benefits of using a CO₂ surgical laser – it seals smaller blood vessels (reducing hemorrhage and increasing visualization of the surgical field), it seals lymph vessels (reducing post-operative edema and swelling), and it seals the ends of cut nerves (reducing post-operative pain).

When the zone of reversible change in the tissue is narrow (100 - 200 microns) initial healing will be delayed for 24-36 hours. That change is quickly reversed, angiogenesis results in new blood vessel growth, and healing after 5-7 days is comparable to tissue cut with a scalpel blade. Improper use of a CO₂ laser can result in a zone of irreversible change in the tissue, thermal necrosis, delayed healing, and incision failure.

CO₂ Laser Safety

CO₂ lasers are high-energy devices that can be used safely. Any responsible CO₂ surgical laser vendor will install the device and train the surgical team in safe operation. The device should be accompanied by appropriate safety glasses for eye protection, a plume capture device, and appropriate signage.

The primary safety concerns with CO₂ lasers are:

- Designating a laser safety officer – in many areas regulatory agencies require that a designated person be in charge of safety for all laser devices used in the practice. The laser safety officer oversees training, signage, and safe use of all laser devices.

- Eye protection - the cornea can be burned by direct or reflected CO₂ laser light. Safety glasses must be worn.
- Respiratory protection – the plume emitted by any device having a thermal effect on tissue should not be inhaled. An appropriate plume-capturing device must be used.

- Fire and explosion protection – dry and flammable materials, including the oxygen rich lumen of anesthetic tubing and endotracheal tubes, can be ignited. These materials must be avoided or covered with wet materials to protect them.

- Reflection protection – CO2 laser light will reflect off metal surfaces and surgical instruments. Adjusting angle of delivery to avoid potentially harmful reflection can be learned quickly.

**CO2 Laser Surgery Technique**

When using a CO2 laser in surgery the goals are:

- No carbon (char) formation
- Minimal change in the tissue left behind
- Minimal post-operative inflammation
- Minimal post-operative discomfort

To achieve these goals the laser power (watts), spot size (diameter of the laser beam contacting the tissue) and delivery mode (continuous, single pulse, or multiple pulse) must be appropriate for the tissue being worked with and the desired effect on the tissue. In general, the best tissue effect occurs when there is the shortest time of exposure of the tissue to laser energy.

Use a combination of power, spot size, delivery mode, and hand speed that allows full thickness incisions to be made in a single pass. Do not “saw” through tissue with multiple partial thickness cuts. Partial thickness incisions result in repeated tissue exposure to the laser beam. Each exposure increases the width of the zone of reversible collateral tissue change. Sawing through an incision with a CO2 laser can lead to irreversible collateral tissue change, thermal necrosis, delayed healing, and incision failure.

Minimize spot size by directing the laser beam perpendicular to the tissue.

Avoid backing away from the tissue and defocusing the laser beam unless the intent is to produce a low temperature, non-evaporative thermal change in the tissue. Defocusing is rarely appropriate unless used for contraction of a tissue area for hemostasis of small vessels. Focusing tips or tipless handpieces should be held 1-3 mm from the tissue surface.

Always place tissue being cut under tension. Tension results in the tissue separating as it is cut, exposing new tissue to the laser beam. Tension is important when dissecting as well as when incising skin.

Use superpulse mode, as discussed below, in less vascular tissue where thermal relaxation of tissue is desirable. Use non-superpulse mode in more vascular tissue where thermal relaxation of tissue may interfere with hemostasis.
Power, Spot Size, and Power Density

Power density is the intensity of the laser beam applied to an area of tissue.

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\text{Power Density} = \frac{\text{Power (watts)}}{\text{Unit Area (cm}^2\text{)}}
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Power density can be altered by changing power or by changing the spot size. Higher power density allows for faster hand speed and shorter time of exposure of the tissue to the laser energy. The shorter the time tissue is exposed to laser energy, the smaller the amount of collateral tissue change.

Hand speed approaching that used with steel instruments is possible by using high power density. Power density dictates how “sharp” a knife the laser beam is – the higher the power density, the sharper the knife.

Older laser texts and instructional material frequently recommend power settings that are too low and spot sizes that are too large. Those settings produce power density below that necessary for effective laser surgery. Follow current recommendations for best results.

How high of a power density should you use in surgery? Each surgeon should establish a maximum comfortable hand speed using a quick but controlled movement along the incision line. At that hand speed power density should be adjusted to produce full thickness incisions in a single pass.

Laser Delivery Mode

Delivery of the laser light to the tissue can be:

- Continuous delivery - the laser energy is delivered for as long as the foot switch is depressed
- Single pulse delivery - one timed pulse of laser energy is delivered when the foot switch is depressed
- Multiple pulse delivery - the laser energy is delivered in a series of timed pulses as long as the foot switch is depressed

In multiple pulse delivery, laser energy is only delivered a portion of the time. For example, in multiple pulse program P7, the laser delivers 20 pulses a second and each pulse is 20 milliseconds long. Thus, in P7, laser light is being delivered 40% of the time.

In multiple pulse delivery, each individual pulse maintains power density, but, because of the pauses between pulses, the rate of tissue removal is slower. Multiple pulse delivery can be very useful to achieve good tissue effect when precision requires slower hand speed.

Multiple pulse programs that deliver as few as two pulses a second can be used for marking lines of incision, and can improve visualization when the laser is used through short scope equipment by allowing time for plume evacuation between each pulse.

The Value of Using Superpulse in CO₂ Laser Surgery

Some CO₂ lasers also give the option of delivering the laser beam in either superpulse (SP) or non-superpulse (NON SP) mode. SP mode produces a series of microseconds long (<800 microseconds) very high-energy (60-80 watts) pulses. The time between each high-energy pulse is longer than the time required for thermal relaxation
(cooling) of the tissue. In SP mode the average power delivered over a period is the power selected on the laser control panel.

In devices equipped with SP capability, SP can be turned on or off whether in continuous, single pulse, or multiple pulse delivery.

Excessive collateral tissue change and char formation occur when tissue absorbs heat faster than it can be released by conduction, convection, circulation and evaporation. Superpulse can help limit collateral tissue change by allowing increased thermal relaxation of the tissue.

Surgeons can control a number of factors that enhance or degrade the superpulse effect. Optimal control of collateral tissue change is achieved by:

- Maintaining an appropriate minimum power setting - at lower power settings, the potential for effective tissue removal is reduced, as each individual pulse may not have enough energy for tissue evaporation. To slow the rate of tissue removal, do not reduce power. Instead, use a multiple pulse program with higher power.

- Maintain correct focal distance - defocusing results in an exponential decrease in power density. For optimal tissue evaporation when using superpulse, keep the laser beam focused!

Note that hemostasis occurs in the zone of reversible collateral tissue change where there is contraction of tissue collagen and sealing of vessels. SP mode can interfere with hemostasis if the zone of reversible collateral tissue change becomes too narrow. NON SP mode is indicated in more vascular tissue where more hemostasis is needed.

**CO₂ Laser Setting Guidelines**

New generation CO₂ laser equipment, with higher maximum power levels, has raised the bar on recommended settings. Current power recommendations have risen significantly because of increased delivery system capability.

Current recommendations are for very high power settings, limited only by the surgeon’s ability to maintain precision and control.

**Skin incisions** –
- .4 mm tip, 15 - 30 watts, continuous wave, non-superpulse
- .25 - .4 mm tip, 10 - 25 watts, continuous wave, superpulse
- .25 - .4 mm tip, 10 - 25 watts, multiple pulse programs D1-D3, superpulse

**Dissection** –
- .4 mm tip, 15 - 30 watts, continuous wave, non-superpulse
- .25 - .4 mm tip, 10 - 25 watts, continuous wave, superpulse
- .25 - .4 mm tip, 10 - 25 watts, multiple pulse programs C1-C3, superpulse

**Ablation** –
- .8 - 1.4 mm tip or ablation nozzle, 12 - 30 watts, continuous wave, non-superpulse
- .8 - 1.4 mm tip or ablation nozzle, 12 - 30 watts, multiple pulse programs P5-7, non-superpulse
- .8 - 1.4 mm tip or ablation nozzle, 12 - 25 watts, continuous wave, superpulse
- .8 - 1.4 mm tip or ablation nozzle, 12 - 25 watts, multiple pulse programs C1-C3, superpulse
In delicate or thinner tissue, use lower power density. In normal or thicker tissue, use higher power density. When working in very vascular tissue with many small vessels, use non-superpulse mode to aid in hemorrhage control.

**Suggested Reading**


Serrano, C. & Rodríguez, J. (2014) Nonsutured Hotz-Celsius technique performed by CO2 laser in two dogs and two


