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Illuminating veterinary surgery: the evolution and application of CO_2 laser technology

Adarsh Kumar[1†], Sara Kaushal[2] and Ankit Ahuja[3]
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur- 176 062 (Himachal Pradesh)

[1]Professor & Head, VCC, [2]Ph.D. Scholar, [3]Assistant Professor, Department of Veterinary Surgery and Radiology, College of Veterinary and Animal Sciences, Palampur.

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The genesis of LASER, an acronym for Light Amplification by Stimulated Emission of Radiation, dates back to Albert Einstein's conceptualization in 1917. Theodore Maiman brought this concept to execution with the development of the first laser, the Ruby laser (Maiman, 1960). In veterinary surgery, the laser found its early applications in laryngeal surgeries in dogs and horses, laying the groundwork for its widespread use in various procedures like liver resections, renal excisions, and tumour removals (Tate *et al.*, 1986).Different types of lasers, including the CO_2 laser, neodymium: yttrium-aluminium-garnet (Nd: YAG) laser, and diode laser, are employed in veterinary surgery, each with distinct tissue effects due to their varying wavelengths (Bolt, 2003).

The CO_2 laser, developed by Dr Kumar C. Patel and colleagues in 1964 at Bell Labs, USA, gained importance for its exceptional water absorption capabilities, making it ideal for soft tissue surgeries (Kaplan and Ger, 1973). It operates by rapidly heating and vaporizing intracellular water, thereby damaging cell membranes (Yang and Chai, 1995). This laser's infrared wavelength is effectively absorbed by soft tissues, constituted of almost 70-75% water content, making it efficient for haemostatic purposes, precise artery welding in microsurgery, anastomosing smaller vessels and nerves, and wound sterilization. Laser power, duration, and spot size dictate incision depth, with minimal thermal impact on adjacent tissues thereby reducing co-lateral thermal damage (Ratz, 1986). It possesses the ability to burn off small nerve endings hence reducing postoperative pain while sealing off lymphatics that help decrease oedema (Aschler *et al*., 1976; Walsh *et al.*, 1988; Mison *et al.*, 2003; Paczuska *et al.*, 2018).

The scope of CO_2 laser technology is broad and diverse, spanning various fields and applications.

In medicine, CO_2 lasers find utility in dermatology, ophthalmology, dentistry, and surgery, offering precise and efficient treatment options with minimal tissue damage. In veterinary medicine, CO_2 lasers assist in surgical procedures, wound management, and tissue ablation, providing benefits such as reduced bleeding and faster recovery times. Additionally, CO_2 lasers play crucial roles in research, industrial work, aesthetic treatments, and defence applications, highlighting their versatility and importance across different sectors. However, the focus of this review article is to summarize the overall significance of CO_2 lasers specifically in the field of Veterinary Surgery.

A comprehensive search was conducted across prominent databases including Google Scholar and PubMed, utilizing keywords such as "CO_2 laser", "Applications of CO_2 laser" and "CO_2 laser in Veterinary Surgery". This search encompassed applied research investigating CO_2 laser technology and its diverse applications. Various literature sources, including original research articles, review articles and case reports, were meticulously reviewed. Articles not directly relevant to CO_2 laser and its applications, as well as those inaccessible in full text, were excluded from consideration. This review strictly adheres to ethical guidelines governing literature reviews, with all sources appropriately cited.

Applications of CO_2 Laser in Veterinary Medicine

Elective surgery: The introduction of CO_2 laser technology has significantly propelled the elective surgery procedures in veterinary surgery. This modality offers precise control and reduces tissue damage, inflammation and postoperative discomfort, thereby enhancing recovery outcomes in small animal patients (Swaim and McGuire, 2004). Common elective surgeries such as canine and feline castration and ovariohysterectomy, tail amputation, and onychectomy in felines benefit from the precision and reduced trauma provided by CO_2 laser technology (Young, 2002).

Oral surgery: CO_2 lasers have become a cornerstone in oral and maxillofacial surgeries since the mid-1960s (Gaspar, 1994), offering precise tissue cutting, vaporization, and haemostasis. The wavelength of CO_2 laser light is readily absorbed by oral tissues, allowing for effective treatment of various

†Corresponding author; E-mail: adarsh9kan@gmail.com

conditions with minimal damage to surrounding structures (Bellows, 2013). The absorbed energy leads to the vaporization of the intracellular and extracellular fluid and it seals blood vessels that are approximately 500µ or less (Barak *et al*., 1990; Carruth, 1991). Clinical applications of CO_2 laser in veterinary dentistry (Strauss and Fallon, 2004) include removing tight frenulum, gingival enlargement surgery, excision of neoplasms, oral biopsies, treatment of oral ulcers, and adjunctive therapy for caudal stomatitis, crown troughing for impressions, and crown elongation, among others (Convissar, 2009). Intraoral use of CO_2 laser promotes wound healing with minimal scarring and allows for unsutured closure, facilitating better patient outcomes (Fisher *et al*., 1983). Laser tech advancements are set to revolutionize minimally invasive surgery (Strauss and Fallon, 2004).

Aural surgery: CO_2 laser surgery is a minimally invasive and effective technique commonly used in veterinary medicine for various ear conditions. The precision of the CO_2 laser enables coagulation, incision, and ablation with minimal post-operative pain and swelling (Gotthelf, 2019; Aslan *et al.,* 2021). Conditions such as otitis externa, aural haematoma, polyps, proliferative tumours, stenotic ear canals, and trauma can be effectively managed with CO_2 laser surgery (Berger and Eeg, 2016). CO_2 laser treatment offers good cosmetic outcomes and minimal scarring, particularly in cases of aural haematomas (Dye *et al*., 2002). Aslan *et al.* (2021) found CO_2 laser surgery effective for treating proliferative otitis externa, which blocks the ear canal opening and vertical canal. It is a viable alternative to total ear canal ablation and bulla osteotomy when possible.

Ophthalmic and adnexal surgery: CO_2 laser surgery has become indispensable in veterinary ophthalmology for procedures involving the eye and adnexa. With the use of a laser wavelength of 10.6 micrometres, the precision and minimal thermal damage of CO_2 laser technology are crucial in delicate eye surgeries, resulting in reduced bleeding, pain, and inflammation (Gelatt and Gilger, 2011; Featherstone and Heinrich, 2010). Common applications include the removal of eyelid tumours, correction of distichiasis, entropion, ectropion, lagophthalmos, nasal fold trichiasis, management of cherry eye, and prolapse of the third eyelid, among others (Stades and van der Woerdt, 2013; Core, 2019). The integration of CO_2 laser technology in veterinary ophthalmology signifies a notable progression, delivering superior safety and efficacy in animal ocular surgeries (Ledbetter and Gilger, 2013).

Dermatological surgery: Veterinary dermatology, a specialized domain within veterinary surgery, focuses on diagnosing and treating skin conditions in animals (Ihrke and Gross, 1992). The CO_2 laser is the primary laser used in veterinary dermatology, offering precise control for incision, lesion excision, and ablation (Duclos, 2006). Various dermatological conditions such as pigmented viral plaques, squamous cell carcinoma, follicular tumours, interdigital cysts, and sebaceous gland tumours can be effectively treated with a CO_2 laser (Duclos, 2019).

Urogenital and perianal surgery: CO_2 laser technology plays a vital role in urogenital and perianal surgeries, providing excellent visualization and precision in highly vascularized tissues (Schultz, 2019). Benefits include reduced recovery times, decreased postoperative infections, and improved patient outcomes (Winkler, 2019). Procedures such as vasectomy, paraphimosis, vulvoplasty, anal gland excision, urethral or vaginal prolapse, perineal urethrostomy, and cystotomy can be performed with meticulousness using CO_2 laser (Schultz, 2019). CO_2 lasers offer exceptional precision, eliminate the requirement for friction, and enable more precise control over incision depth.

Oncological surgery: In surgical oncology, achieving clean margins during tumour excision with the aim of cure is paramount. The use of CO_2 lasers in oncological procedures has emerged as a viable alternative to traditional radical tumour resections and palliative treatments (Paiva *et al*., 2002). It may be considered a useful modality with potential advantages such as precision in tissue cutting, improved visibility of the operative field, haemostasis, sealing of nerve endings and lymphatics, and decreased wound contamination during the procedure (Berger and Eeg, 2006; Holt and Mann, 2002; Paczuska *et al.,* 2014). According to Patel *et al.* (2013), the use of laser for the surgical management of warts and small tumours results in less surgical time and decreased blood loss along with a good cosmetic appearance of the scar. Since the CO_2 laser is used in a non-contact mode, it significantly lowers the risk of seeding tumour cells compared to traditional surgical excision methods (Holt and Mann, 2002; Lanzafame *et al*., 1986b). Studies have shown that excision of tumours with a CO_2 laser leads to reduced local recurrence of tumours, fewer chances of metastasis, and increased survival rates (Lanzafame *et al*., 1986a; Tuchmann *et al.,* 1986).

Equine laser surgery: In equine surgery, CO_2 lasers provide precise, minimally invasive treatment options with faster recovery and better cosmetic results (Baird and Clark, 2015). CO_2 laser technology presents notable advantages over conventional surgical methods, which can be more invasive and traumatic for equines. Horses undergoing CO_2 laser surgery often experience reduced surgical trauma and quicker recovery times, crucial for their functional restoration, especially in performance horses (Smith, 2018). Furthermore, CO_2 lasers have been shown to yield superior cosmetic outcomes, a critical consideration in the aesthetic evaluation of show horses (Hanson *et al.,* 2019). Various applications of CO_2 lasers include the removal of cutaneous masses such as sarcoid, ablation of adnexal masses, management of contaminated wounds, granulation tissues, and palmar/plantar digital neurectomy (Palmer, 1996; Orsini, 2002; Tate and Tate, 2019).

Exotic animals' surgery: CO_2 laser technology is increasingly used in exotic animal medicine, offering decreased blood loss, reduced surgery time, and enhanced accuracy (Rupley and Parrott-Nenezian, 2002). CO_2 laser provides enhanced accuracy while minimizing collateral thermal damage (Winkler, 2019). Various surgical procedures can be conducted using CO_2 lasers at different power settings, including skin incisions, removal of cutaneous, abdominal, or mammary growths, celiotomy and laparotomy procedures, orchidectomy, ovariohysterectomy, and abscess management in rabbits, rodents, ferrets, sugar gliders, iguanas, avians, and other animals. Additionally, CO_2 lasers can be utilized for procedures such as adrenalectomy, insulinoma removal, anal sacculectomy in ferrets, and limb amputation in reptiles (Rupley and Parrott-Nenezian, 2002; Hadzima *et al.,* 2019).

Limitations of CO_2 Laser

Despite the manifold advantages of CO_2 laser surgery, several considerations must be taken into account. One of the primary drawbacks pertains to the substantial initial investment required for CO_2 laser equipment. The maintenance of these lasers is imperative to ensure their ongoing functionality and safety. Additionally, proficiency in the operation of CO_2 lasers demands specialized training to ensure their effective and safe use (Winkler, 2019).

CO_2 lasers are not suitable for use in fluid mediums, and their endoscopic application is hindered by the limited availability of appropriate terminal attachments, making their use impractical or difficult. Other drawbacks include lower healing of the incisions made by a CO_2 laser during the initial postoperative days as compared to a scalpel. There may be chances of over-penetration thereby damaging the underlying viscera. Additionally, the CO_2 laser's efficacy is limited when applied to bone and other hard tissues. Notably, surgical and postsurgical complications remain possible in any surgical procedure, notwithstanding the adherence to precautions. While the implementation of the CO_2 laser aims to mitigate these complications, complete elimination thereof remains unattainable. Lasers also produce smoke that may contain viable infectious microorganisms and cytotoxic particles, necessitating the use of a smoke evacuator (Bolt, 2003; Pizzi, 2009).

Economic Considerations for Laser Surgery

The decision to adopt laser surgery in a veterinary practice involves economic considerations similar to any other technology. With the rapid advancements in veterinary surgery, practitioners are faced with the challenge of keeping pace with scientific progress. As society eagerly embraces each technological advance, veterinarians are driven to adapt and evolve alongside shifting societal expectations. While the adoption of new technology undoubtedly improves patient care, the associated expenses can be significant, sometimes surpassing the financial capabilities of veterinary practitioners. The balancing act between optimal patient care and financial constraints has long been a concern in veterinary practice, a distinctive aspect of the field that sets it apart from human medicine.

The CO_2 surgical laser offers both enhanced patient care and economic benefits for veterinary practices. Its use reduces surgical time and postoperative complications, leading to lower labour costs. Additionally, procedures performed with the CO_2 laser often command higher fees, resulting in increased revenue for veterinary hospitals. Consequently, many practitioners prefer CO_2 laser surgery over conventional methods due to its advantages, leading to broader acceptance among clients. Overall, the CO_2 laser presents an attractive option for both elective and non-elective surgical procedures in veterinary practice (Irwin, 2002; Young, 2002; Godbold, 2019).

Conclusions

In conclusion, the incorporation of CO_2 laser technology into veterinary surgery represents a significant advancement that offers numerous benefits for both patients and practitioners. From elective surgeries to specialized procedures, the precision and efficiency of CO_2 laser surgery improve patient outcomes while also presenting economic advantages for veterinary practices. Despite initial investment costs, the long-term benefits, including reduced surgical time, lower complication rates, and increased revenue potential, make CO_2 laser surgery a compelling option for veterinary hospitals. As the field of veterinary surgery continues to evolve, embracing innovative technologies like the CO_2 laser ensures that practitioners can deliver the highest standards of care while navigating the economic realities of their profession. With its proven efficacy and economic viability, CO_2 laser surgery stands as a testament to the ongoing commitment of veterinary professionals to embrace advancements that enhance both patient welfare and practice sustainability.

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