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Review Article

The laser in veterinary medicine

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Abstract: The development of non-invasive, non-toxic, and non-pollutant methods for the treatment of different illnesses represents a constant concern of scientists from the medical field worldwide. In this category fit the methods based on the use of laser systems, which are successfully applied both in human and veterinary medicine due to the special properties of laser radiation: monocromaticity, coherence, intensity, and directionality. The aim of this paper is to present the laser systems used in several domains of veterinary medicine and some experimental results obtained by different authors.

Key words: Laser surgery, photodynamic therapy, laser phototherapy, veterinary medicine

Fields of laser use in veterinary medicine

Protecting life and human and animal health is a constant concern of both doctors and specialists in various fields (biochemistry, biophysics, biology, etc.). Their joint efforts have led to the development of new methods of treatment based on new discoveries and technology including laser.

The first use of lasers in veterinary medicine was in larynx surgery in dogs (1) and horses (2). The results obtained in these early studies paved the way for the current use of the laser in general surgery, small animal targeting liver lobe resection, partial excision of the kidneys, and tumor excision or resection (intra-abdominal, intra-thoracic, breast, brain).

At the same time, experiments on the use of laser for photodynamic therapy of tumors in animals and laser phototherapy have begun.

In the field of photodynamic therapy, only a few studies have been published concerning the treatment of esophageal carcinoma cells in dogs (3,4), oral carcinoma cells in dogs (5), prostate cancer (6-9), skin cancer (10-12), and brain tumors (13,14). This small number of studies has determined the limitation of the application of photodynamic therapy in veterinary oncology. Another limitation is related to the depth of penetration of visible radiation, which means this treatment modality can be applied only on superficial cancers or requiring the use of fiber optics for deep interstitial irradiation. Despite these limitations, clinical studies show that photodynamic therapy has some advantages over radiotherapy, with respect to the number of treatment sessions required to achieve the same therapeutic efficiency (15). Hence the hope that photodynamic therapy can be developed as an alternative treatment in veterinary medicine, it being currently applied in several

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medical centers in the world, such as Oklahoma State University (USA), Colorado State University (USA), The Park Pet Hospital (USA), Washington State University (USA), Centre Hospitalier Universitaire Vaudois Hospital, Lausanne (Switzerland), The Netherlands Cancer Institute (The Netherlands), University Hospital Groningen (The Netherlands), Clinica Chirurgica Veterinaria, Milano (Italy), St John's Institute of Dermatology, London, (Great Britain), Queen's Veterinary School Hospital (Great Britain), Heinrich-Heine-University (Germany), Fukui Medical University (Japan), and Institute for Cancer Research (Norway).

Another field of use of laser in medicine is laser phototherapy, which was first introduced in 1968, by Mester et al. (16). This therapeutic method has found applicability in the field of veterinary medicine to treat medical conditions: osteo-articular conditions (arthritis, tenosynovitis, and arthrosis) or wounds on race horses (17-20), and skin and dental diseases in farm animals (21), as well as chronic otitis external plantar bursitis, tendinitis, granulomas, small wounds and ulcers in small animals (22-25).

In these medical applications (laser surgery, photodynamic therapy, and laser phototherapy) are used both high power laser systems and low power laser systems emitting continuously or in pulses: CO_2 laser (λ = 10,600 nm, continuous/pulsed), Ar ion laser (λ = 488/514 nm, continuous), He-Ne laser (λ = 632.816 nm, continuous), dye laser (λ = 450-900 nm, continuous/pulsed), laser diode (λ = 670-980 nm, continuous/pulsed), Nd:YAG laser (λ = 1064 nm, pulsed), Ho:YAG laser (λ = 2120 nm, pulsed), Er: YAG laser (λ = 2940 nm, pulsed), ruby laser (λ = 694 nm, pulsed), etc. These laser systems are used in veterinary medicine depending on the purpose and conditions to be treated.

The purpose of the present paper is to present some applications of these laser systems in veterinary medicine.

High power laser use in veterinary medicine

The thermal or ablative effects induced by high power laser radiation in biological tissues underline their use in veterinary surgery.

The conventional surgical methods are sometimes accompanied by tissue injury due to wounds that appear and, therefore, can be complicated by the emergence of infections, hemorrhaging or keloid scars. These complications can be removed by using new surgical methods based on electricity use (electrosurgery) or high power laser radiation (laser surgery).

In veterinary medicine, high power lasers have found applications in treating certain diseases of soft tissues (skin, oral mucosa, respiratory mucosa, the urogenital mucosa, muscles) and hard tissue (bone and cartilage).

High power radiation in the treatment of soft tissue disorders

Skin disorders

Early studies on the use of minimally invasive surgery (MIS) in the treatment of skin diseases focused on the use of laser radiation emitted by CO_2 lasers (λ = 10,600 nm).

Studies performed by Slutzki et al. (26) have shown that a precise excision (thermal effect) can be obtained when using laser radiation power (15 ÷ 25) W and beam diameter (0.1 ÷ 0.2) mm. To achieve the total vaporization of an area of injured skin (ablative effect), Ratz (27) demonstrated that useful laser parameters are: power (4 ÷ 10) W and beam diameter (1 ÷ 3) mm.

These examples clearly demonstrate that the effects induced by laser radiation in biological tissues are dependent on laser beam parameters.

Similar studies on the application of laser surgery in the treatment of skin diseases in horses (neoplasm, granuloma, hematoma, and warts) were conducted also by Palmer (28) and Palmer and McGill (29), which highlights some medical advantages of using high-power laser radiation in soft tissue surgery.

These advantages are related to controlled bleeding (compared with traditional methods), sterilized tissue, decreased postoperative discomfort and healing without postoperative complications, and no side effects.

Urogenital disorders

Use of laser radiation in surgical treatment of urogenital diseases was introduced for the first time by Fayez et al. (30), who used the CO_2 laser for the treatment of endometrial cysts.

In 1993, Bilkslager (31) reported that the YAG: Nd laser is more effective than CO_2 laser for removal of endometrial cysts, presenting a better hemostatic effect in the urogenital highly vascularized area.

To treat inaccessible urogenital areas, laser surgery can be applied using optical fiber for transmitting laser radiation to the areas to be treated (laparoscopic method).

Respiratory disorders

The first study on the use of a CO_2 laser for the excision of vocal nodules in dogs was conducted by Jako (1) and it represented the first use of laser radiation in veterinary medicine. Subsequently, laser microsurgery techniques have been widely used in veterinary surgery of laryngeal disorders in horses.

Complications caused by poor hemostasis that occurs during CO_2 laser excision have determined the use of another laser system in veterinary surgery such as the YAG: Nd laser. This laser system has proven to be more effective than the CO_2 laser for treatment of ethmoidal hematoma, cysts, polyps, lymphoid hyperplasia, epiglottic entrapment, dorsal displacement of soft palate, and ablation of the guttural pouches (32-36).

In order to transmit the laser radiation to difficult to reach affected areas, there is the possibility of using optical fiber enabling the achievement of surgery under local and not general anesthesia, and reducing the period of convalescence.

Disorders of ocular tissues

Ophthalmology is another area of veterinary medicine where the use of high power laser radiation was introduced in the early 80s.

Lasers used in veterinary ophthalmologic surgery are the YAG:Nd laser, Ar ion laser, and semiconductor lasers. These systems are used for the treatment of glaucoma, a disease commonly seen in dogs.

Gallstones and kidney stones

The laser treatment method of gallstones and kidney stones is based on the ablative effects induced by high power laser radiation in biological tissues.

High power laser radiation used in urology and gastrointestinal surgery for gallstones and kidney damage is that emitted by the dye laser (λ = 504 nm, t_{puls} = 1 ms) (37,38) and Ho:YAG laser (λ = 2.1 mm, $t_{puls} \in (250 \div 300)$ ms) (38).

The destruction of gallstones and kidney stones depends on their composition, the treated animal, and laser parameters. Thus, the radiation emitted by the dye laser is more effective for destruction of gallstones in horses than the radiation emitted by Ho:YAG laser, while radiation emitted by Ho:YAG laser is more effective for the destruction of gallstones in other categories of animals such as dogs, pigs, and cows.

High power laser radiation in the treatment of hard tissue diseases

Applications of high power laser radiation to treat hard tissues are fewer, being limited because of economic and technical reasons.

The first use of high power laser radiation in hard tissue surgery was reported by Nixon et al. (39), who used pulsed CO_2 laser for the treatment by evaporation of bone deformities. Subsequent studies have been conducted by various researchers including Collier et al. (40), who used the Ho:YAG laser for the treatment of articular cartilage and subchondral bone after traumatic injuries obtaining satisfactory results, and Dickey et al. (41), who used the same laser for the ablation of intervertebral discs (from T10-11 to L3-4) on dogs. The author reported a recurrence rate of 5% of the disease (intervertebral discopathies) and minimal effects of postsurgical complications (necrosis and collateral thermal effects).

The activities on the use of high power laser radiation in this area are still ongoing, based on the encouraging results obtained so far.

Low-power lasers' use in veterinary medicine

Low-power laser radiations induce in biological tissues mainly photochemical effects. Two types of experimental treatments applied in veterinary medicine are based on these photochemical mechanisms: photodynamic therapy and laser phototherapy (low level laser therapy).

Photodynamic therapy

Photodynamic therapy is a local treatment modality for cancer, based on the administration of a photosensitive substance selectively retained in the tumor and after irradiation with optical radiation results in the destruction of the tumor tissue in the presence of molecular oxygen. Interaction of these 3 essential constituents: the photosensitive substance, the light radiation (with the wavelength corresponding to maximum absorption of the photosensitive substance), and oxygen, leads to direct effects (direct damage to cells) or indirect effects (vascular and inflammation reactions).

To date, in veterinary medicine, only a few studies have been published concerning the application of photodynamic therapy in treatment: esophageal squamous cell carcinoma in a dog (42,43), oral carcinoma cells in dogs (44), prostate cancer, skin cancer (45), osseous tumors (46), and brain tumors (47), and only a few photosensitizers have been tested: 5-aminolevulinic acid, meso-tetra-(m-hydroxyphenyl) chlorine, benzoporphyrin derivatives, Al-phthalocyanine, benzophenothiazine, and Photofrin II**.**

These studies show that photodynamic therapy presents some advantages compared to radiotherapy regarding the number of treatments necessary to achieve the same therapeutic effectiveness. From here we can hope that photodynamic therapy can be developed as an alternative therapy in veterinary medicine.

Laser phototherapy

Laser phototherapy is based on laser radiation absorption by cytochromes and porphyrins, from mitochondria and cell membranes, which pass from the singlet ground state ^{0}S in the first excited singlet state $^{1}S^{*}$. From the excited state, absorbing molecules can be returned to the ground state by radiative or non-radiative transitions or energy interchange can take place and thus pass to the triplet excited state $^{3}T_{1}^{*}$. Molecules in the triplet excited state transfer their excitation energy to the molecular oxygen (which is in the triplet state in its ground state), which passes to its lowest state, the excited singlet. Singlet oxygen is part of free radicals and is one of the most active forms in cellular metabolism.

Production of singlet oxygen leads to the formation of proton gradients across cell membranes and mitochondrial membrane. These gradients of protons change the permeability of cell membranes to different ions and mitochondrial membrane permeability, which leads to metabolic changes in the cell. These metabolic changes induced by low power laser radiation at the cellular and subcellular level lead to the development of procedures for the treatment of soft and hard tissue diseases.

Laser phototherapy in the treatment of soft tissue disorders

Soft tissue disorders that can be treated by laser phototherapy are wounds, sprains, musculoskeletal dysfunction, neuropathy, and various sports injuries after accidents (e.g., from contusions to muscle strains in horses).

Wounds

The frequent appearance of wounds with different etiologies in animals has prompted the scientific world to turn its attention to new, faster, more economical, and nontoxic therapies. This targeting of research directions in the treatment of wounds also attracted the attention of Mester et al. (16), who used for the first time a low power laser in the treatment of wounds in rats, aiming to develop a non-invasive laser method, nontoxic, economic, and sterile to replace surgery.

The stimulation effect of low power laser radiation on postoperative wounds healing, trauma, septic, refractory to other treatments, and superficial wounds (cuts, scratches, granulomas, ulcers, fistulas) entered the concerns of many researchers (19,48,49) who conducted experiments and developed methods of treating wounds in horses and dogs. Studies have shown that the use of low-power laser radiation leads to acceleration of healing, formation, and reorganization of new blood vessels (angiogenesis), epithelial and dermal tissue regeneration, increased fibrogenesis, and collagen synthesis.

These studies led to the development of laser-targeted therapies to solve certain cases that are currently presented in some veterinary clinics in many countries.

Inflammation

The use of low-power laser radiation in treating inflammations has been the focus of various researchers around the world. Pathologies they addressed were related to acute and chronic inflammation of region first phalanx, local infectious inflammation (mastitis, thrombophlebitis, abscesses, chronic sinusitis, otitis, etc.), inflammation accompanying various injuries (acute sprains, muscle and capsular rupture, hematoma), and acute and chronic tendinitis. In order to treat inflammation, laser systems with continuous or pulsed emission were used. Petermann (50) used a pulsed laser system (P_{peak} = 60 W/90 W, t_{puls} = 200 ns) for the treatment of local inflammations (arthritis and tendosinovitis) in horses, while Stella et al. (51) used the He-Ne laser (continuous emission) to treat temporomandibular inflammation in dogs. A comparative study conducted by Bjordal et al. (52) showed that the pulsed laser systems are more efficient than the continuous laser system to treat different types of infection/inflammation.

Neurological disorders

Neurological disorders in dogs and horses which can be treated by laser phototherapy are those due to trauma (caused by shocks), paresis and neuralgia (53). Effects of low power laser radiation on the nervous system are regulating nervous system function, pain relief, and nerve regeneration.

There are only a few studies on the application of laser in this area and research should be continued to substantiate the therapeutic method.

Laser phototherapy in the treatment of hard tissue

The literature mentions the use of low power laser in treating the following types of hard tissue diseases: disorders of the spine, joints, and fractures (54,55). The results presented in these studies are cartilage regeneration (pulsed or continuous laser; horses and dogs), increasing the speed of recovery of the bone (pulsed laser system; dogs), pain relief in the cervical and thoracolumbar region (pulsed laser; horses), and neck pain relief (pulsed or continuous laser; dogs). These studies do not provide, however, the full set of laser parameters used; therefore, results may not be reproduced at a veterinary clinic. It can only be considered that the reported laser parameters and investigations should be carried out to determine the other missing parameters.

All these results obtained to date may be the basis for the development of new laser systems and therapeutic procedures that will lead in future to the expansion of applications of laser techniques in veterinary medicine.

Conclusion

The clinical applications of lasers, initially confined to surgery, have been extended in recent years to almost all areas of veterinary medicine. This wide use of lasers in veterinary medicine opens new perspectives in the treatment of soft and hard tissue diseases as an alternative, non-invasive, non-toxic, and low cost method for the benefit of patients.

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