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Review

The use of lasers in veterinary ophthalmology: Recommendations based on literature

Laseranwendungen in der Veterinär-Ophthalmologie: Empfehlungen auf Basis der Literatur

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Abstract

Lasers are routinely used in veterinary ophthalmology for the treatment of a number of ophthalmic conditions and diseases. In veterinary ophthalmology, gas lasers (CO_2 lasers) and semiconductor lasers (diode lasers) are used primarily, but the therapy of posterior capsular opacification with the Nd:YAG laser has also been described. This paper presents and discusses the most common indications for the use of the diode and CO_2 lasers. Diode lasers are mainly used in the treatment of glaucoma, either by transscleral cyclophotocoagulation or by endoscopic cyclophotocoagulation. Other indications are various forms of retinal detachments, as well as pigmented neoplasms of the uvea. An emerging field in veterinary ophthalmology using diode lasers is photodynamic therapy of periocular tumors. CO_2 lasers are used for pars plana vitrectomies and surgical excision of ocular tumors.

Keywords: diode laser; carbon dioxide laser; ophthalmic surgery; animal.

Zusammenfassung

Laser werden in der Veterinär-Ophthalmologie zur Behandlung unterschiedlicher Augenveränderungen und -erkrankungen regelmäßig eingesetzt. Es kommen hauptsächlich Gas (CO_2)- und Halbleiterlaser (Diodenlaser) zur Anwendung, aber auch der Nd:YAG-Laser wird eingesetzt, bspw. zur Therapie des Nachstars (posterior capsular opacification, PCO). Im vorliegenden Artikel werden die häufigsten Indikationen zur Verwendung von Dioden- und CO_2-Lasern vorgestellt und diskutiert. Diodenlaser werden hauptsächlich zur Therapie des Glaukoms eingesetzt, sei es mittels transskleraler oder mittels endoskopischer Zyklophotokoagulation. Andere Indikationen sind verschiedene Formen der Netzhautablösung sowie pigmentierte Tumoren der Uvea. Ein neu aufkommendes Einsatzgebiet für Diodenlaser ist die photodynamische Therapie von periokulären Tumoren. CO_2-Laser werden in erster Linie für die Pars-plana-Vitrektomie beim Pferd und zur Exzision von Tumoren verwendet.

Schlüsselwörter: Diodenlaser; CO_2-Laser; Augenchirurgie; Tier.

1. Introduction

While lasers have been employed in human ophthalmology since the 1970s [1, 2] and have a wide field of applications [3–9], the earlier laser units, such as argon, krypton and the first Nd:YAG lasers were not really suitable for use in veterinary medicine because they were large and heavy units requiring an elaborate cooling system. The advent of the portable semiconductor (diode) lasers has made laser surgery both feasible and affordable for veterinary use [10, 11]. In veterinary ophthalmology lasers are mainly used to treat various forms of glaucoma, retinal detachments, and pigmented ocular tumors. Therapy of posterior capsular opacification (PCO) with Nd:YAG lasers have also been described [12].

This paper presents and discusses the most common indications for the use of diode and CO_2 lasers including the emerging field of photodynamic therapy of periocular tumors.

2. Semiconductor (diode) lasers

Presumably the most common laser used in veterinary ophthalmology is the diode laser emitting light at a wavelength of 810 nm [11]. As a semiconductor laser, the unit is lightweight and therefore transportable and does not require extensive cooling systems. The laser light is delivered through an optical fiber directly to the required tissue [9]. The most commonly used diode laser (DioVet®; IRIS Medical Employment, Den Haag, The Netherlands) emits laser light at 810 nm thereby targeting pigmented tissues. The maximum energy is 2000 mW, and an exposure duration of up to 9000 ms (Figure 1) [13].

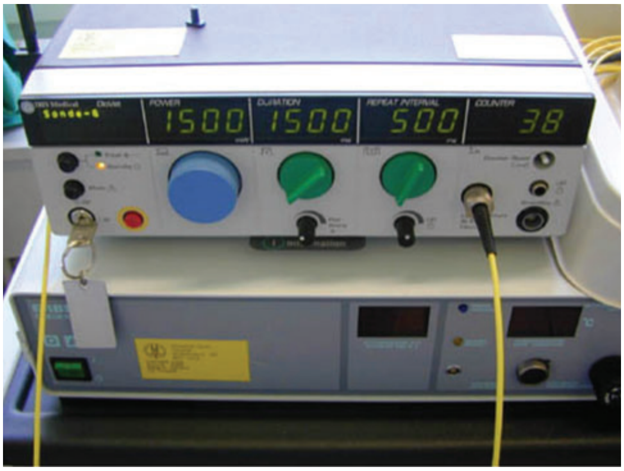

Figure 1 Front panel of the diode laser DioVet® (IRIS Medical Employment, Den Haag, The Netherlands).

2.1. Transscleral laser cyclophotocoagulation

Diode lasers are routinely used to treat various forms of primary glaucoma in dogs, cats and horses [11, 14–18].

The goal is to partially destroy the non-pigmented ciliary epithelium, to reduce aqueous humor secretion, and thus decrease intraocular pressure (IOP). The laser energy delivered is captured by the neighboring pigmented ciliary epithelium, and the resulting thermal effects also affect the non-pigmented epithelium.

In small animals, the laser probe is positioned perpendicular to the sclera and 3 mm posterior to the limbus (dorsal hemisphere), or 4 mm posterior to the limbus (ventral hemisphere). In horses the probe is positioned 4–6 mm posterior to the limbus (Figure 2) [16, 19, 20].

The 3 o'clock and 9 o'clock positions and the posterior ciliary arteries are avoided [11]. The original settings were 1500 mW and 1500 ms for 36 spots. This energy level should cause a popping sound (photodisruption) in about 20% of the spots, indicating an effective level of energy. However, photodisruption caused considerable postoperative uveitis, and consequently the settings were changed to 1000 mW and 3–5000 ms.

Photocoagulation, not photodisruption, is achieved with these settings [21]. Some surgeons treat only a small number of spots at a given time and repeat the treatment as needed to titrate IOP to the target pressure of <20 mm Hg.

Figure 2 Glaucoma probe for transscleral cyclophotocoagulation.

One of the pitfalls of transscleral laser photocoagulation is post-operative pressure spikes, which have to be carefully monitored and treated.

Other methods of cyclophotodestruction/-ablation include cyclocryotherapy. This is an established method in glaucomas that are non-responsive to medical therapy. The expected destruction was rather unpredictable and sometimes short-lived. A serious complication of this treatment was the occurrence of retinal detachments [22].

2.2. Endocyclophotocoagulation

In recent years endoscopic laser cyclophotocoagulation [23] has been advocated but controlled studies of its long-term usefulness in animals are as yet lacking. This procedure involves the introduction of a diode laser probe and the transmission of laser light into the anterior chamber. The ciliary sulcus is extended with viscoelastic substances and the probe is advanced toward the ciliary processes. The ciliary epithelium is laser-treated in a controlled fashion over 270–360 degrees of the pars pilcata. Since cataract formation is a frequent complication of endolaser surgery, the procedure is best performed on aphakic or pseudophakic patients [24, 25].

2.3. Transscleral laser retinopexy

Retinal detachments, so-called giant tears, are frequent complications of intracapsular extraction of luxated lenses in dogs and cats, but they can also occur spontaneously. The retinal disinsertions at the level of the ora ciliaris retinae can be avoided by prophylactic transscleral retinopexy [26]. In certain breeds of dogs, rhegmatogenous retinal detachments are frequent complications after extracapsular cataract surgery and these can also be prevented by transscleral retinopexy. In general, 4–5 rows of spots are applied beginning 10 mm posterior to the limbus with a total of 65–75 spots. The recommended settings are 800 mW and 1000 ms [26].

Cryopexy of detached retinas has been used in canine vitreoretinal surgery [27], but has largely been replaced by laser retinopexy. The delivery of thermal energy to actively seal the retina to the underlying RPE appears to be more precise and effective with laser treatment.

2.4. Transpupillary laser retinopexy

Occasionally circumscribed bullous retinal detachments or localized retinal tears are encountered in animals. Usually these are incidental findings since such localized lesions rarely lead to recognizable visual deficits.

If these lesions are not located in the far periphery of the ocular fundus, they are amenable to treatment via an indirect diode laser ophthalmoscope (Figure 3). For optimal positioning and immobilization of the globe, the patient is anesthetized and the pupil maximally dilated. With the indirect ophthalmoscope and a 20 diopter condensing lens, the laser beam is focused on the exact retinal spots to be treated [28]. The spot size at the level of the ophthalmoscope is usually 0.4 mm and the focal length 35.6 cm [29]. Settings vary between

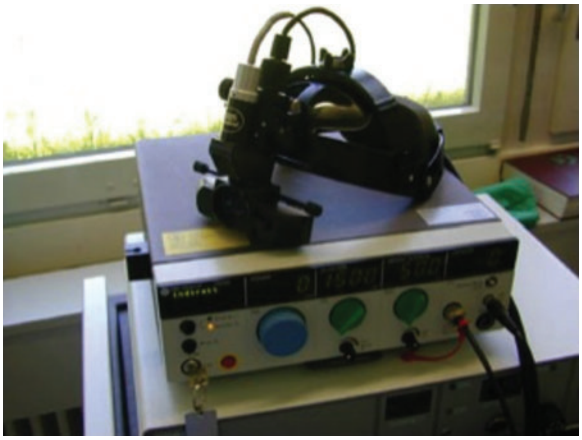

Figure 3 Indirect diode laser ophthalmoscope (DioVet®; IRIS Medical Employment, Den Haag, The Netherlands).

100 and 200 mW and 100 and 600 ms, based on the observed effect. Less energy is required in the nontapetal fundus compared to the tapetal area. In the nontapetal fundus laser burns are immediately recognized as whitish spots, while in the tapetum the spots have a bronze-like color (Figure 4A,B). The result is a focal coagulation necrosis effectively sealing the retina to the underlying pigmented epithelium [28]. Large retinal vessels should be avoided to prevent hemorrhage. The laser spots are placed next to one another to prevent liquefied vitreous entering between neuroretina and pigmented epithelium, thus limiting the retinal detachment or tear to the immediate area [28].

2.5. Iris melanoma (choroidal melanoma)

The diagnosis of iridal melanoma is based on the following parameters: (1) dark brown pigmented lesion, (2) loss of normal texture of the superficial iridal stroma, (3) thickened and velvety lesion, (4) dyscoria and inhibition of normal pupil mobility, and (5) gonioscopic involvement of drainage angle structures [30]. Fine needle aspirations of uveal tumors may confirm the clinical diagnosis, although the small number of cells and the heavy pigmentation encountered in most cases render cytopathology difficult [31].

Iridal melanomas are the most common primary intraocular tumors in dogs and cats (Figure 5). They are locally invasive and may lead to hemorrhage and secondary glaucoma [32–34]. They may also metastasize to different locations [34–36]. If diagnosed early, they can be successfully treated. Tumors limited to the iris stroma without involvement of the drainage angle carry a favorable diagnosis. Flat lesions are preferable because of the limited penetration of laser energy. The thickness of such lesions can be measured using high resolution ultrasound (≥20 mHz) [37].

The special adapter for the operating microscope allows delivery of laser energy through the cornea by aid of a joystick without any collateral damage at the level of the cornea (Figure 6) [38]. The spot size is 0.3 mm and the energy level is between 100 mW and 1000 mW depending on the observed effect. In continuous mode, the tissue effect can be monitored directly (Figure 7). Desirable effects are obvious shrinking of the tissue and as a consequence, a deformation of the pupil. Photodisruption with dispersion of pigmented tissue should be avoided by carefully adjusting the energy level [29].

Preoperatively, the pupil is kept miotic with 1% pilocarpine drops. At the end of the treatment, the pupil should be dilated with 1% atropine sulfate and the eye should be treated with anti-inflammatory eye drops. Laser treatment of suspected uveal melanomas may have to be repeated after several weeks, especially in tumors with an average thickness of >2 mm.

Choroidal melanomas are diagnosed infrequently in domestic animals (Figure 8) [39–43]. Laser therapy of choroidal melanomas has not been described in animals. It could potentially be treated in a fashion similar to transpupillary laser retinopexy.

For small circumscribed neoplasms of the iris, laser therapy is less invasive and technically less demanding compared with sector iridectomies. For the rare choroidal melanomas, laser therapy offers a potentially effective and feasible treatment

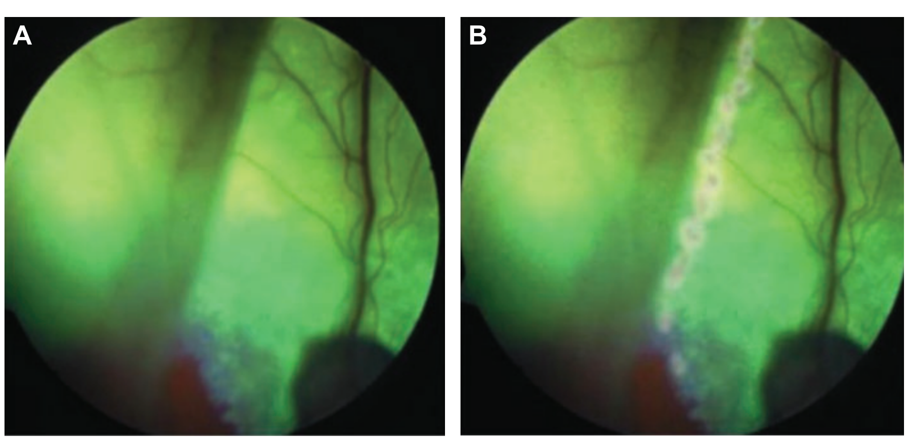

Figure 4 (A) Bullous retinal detachment in a dog prior to barrier retinopexy. (B) The same lesion immediately after laser retinopexy. Note the whitish spots.

Figure 5 Uveal (iridal) melanoma in a dog.

option. In people, proton radiation is the treatment of choice for similar tumors [44].

2.6. Epibulbar (limbal melanoma)

Limbal or epibulbar melanomas occur more often in dogs than in cats [45–49]. They originate from the outer pigmented band of the limbus and manifest as darkly pigmented masses riding on the limbus and extending into the cornea (Figure 9) [50]. Gonioscopy shows no involvement of the adjacent angular structures.

Traditionally they have been treated by keratectomy/sclerectomy [47, 48]. Surgical removal of limbal melanomas can be followed by cryotherapy of remaining neoplastic cells. Surgical debulking of limbal melanomas, followed by diode laser photocoagulation, has been described [51]. However, this leads to superficial carbonization of tissue, and in the author's opinion, cryotherapy is superior to laser photocoagulation [13].

2.7. Uveal cysts

Uveal cysts are common in dogs, with a breed predilection for Golden Retrievers, Labrador Retrievers and Boston Terriers [52]. They are present as round, fluid filled structures of variable

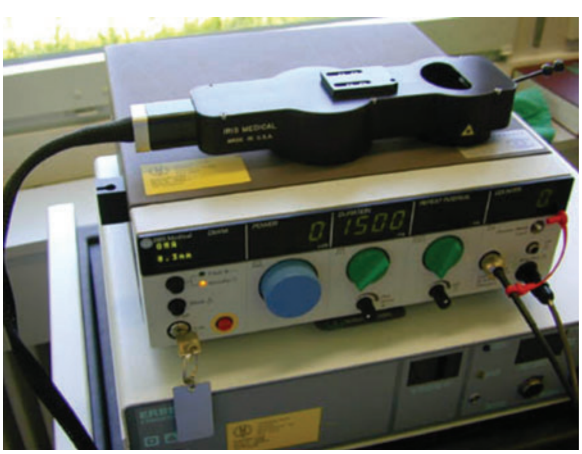

Figure 6 DioVet® with operating microscope attachment for the Leica operating microscope.

Figure 7 Intraoperative image of an uveal melanoma treated with the DioVet® (settings: 400 mW, 300 ms). The focused red dot is on the tumor, the lighter spot is the reflection from the cornea.

size with a thin pigmented and often translucent wall (Figure 10). They arise from the iris, the ciliary body or are found free-floating in the anterior chamber (Figure 11). Deflation with a diode laser of such cysts has been described in dogs, cats, and horses [53, 54]. While there have been no adverse effects reported with this treatment modality, the cyst wall will remain within the anterior chamber and often collapses against the corneal endothelium [54, 55]. It may not be possible to deflate poorly pigmented uveal cysts with a semiconductor laser [56]. Iris cysts can also be easily removed from the anterior chamber by aspiration with a small gauge needle [57].

2.8. Distichiasis

Distichiasis is a common ocular disorder in dogs, but appears to be rare in other domestic animals (Figure 12) [58, 59]. Initially, distichiasis has been managed by partial tarsal plate removal [60]. However, this caused frequent distortion and scarring of the lid margin and was later abandoned and

Figure 8 Choroidal melanoma in a dog (incidental finding).

Figure 9 Epibulbal (limbal) melanoma in a dog.

Figure 10 Free-floating uveal cyst in the anterior chamber (AC) of a dog. The cyst has gravitated to the bottom of the AC.

Figure 11 Large uveal cyst in a dog obstructing the pupil. The cyst is in the process of being removed by aspiration.

Figure 12 Distichiasis in a dog. Note that several distichiae may emanate from one Meibomian gland opening.

replaced by cryotherapy [61, 62]. With this method a destruction of the hair follicle was achieved with minimal damage to the surrounding tissue. The same can be achieved using laser photocoagulation [63]. As yet this has not been reported in veterinary ophthalmology.

2.9. Photodynamic therapy of periocular squamous cell carcinoma

A relatively new use of semiconductor lasers is photodynamic therapy for the treatment of periocular squamous cell carcinoma (SCC). The first reports have been promising [64, 65].

The tumors were surgically resected and the resulting wound beds were infiltrated with 2-[1-hexyloxyethyl]-2-devinylpyropheophorbide-a. The wounds were then irradiated with a 665 nm diode laser. Usually a single therapeutic cycle is necessary to achieve remission of the tumors.

3. Gas lasers (carbon dioxide lasers)

Carbon dioxide (CO_2) lasers are widely used in soft tissue surgery [66–70] and are also used in ocular surgery [13, 71, 72].

3.1. Sclerotomies for pars plana vitrectomies

As CO_2 lasers allow precise cutting of tissue and provide hemostasis at the same time, they have been widely used for sclerotomies to gain access to the vitreous cavity in pars plana vitrectomy in horses [73–78]. A first sclerotomy is performed 10 mm posterior to the limbus and slightly dilated with a lacrimal dilator if needed. The irrigation port is introduced in this opening and sutured to the sclera. The second sclerotomy is done in a similar fashion to accommodate the vitrectomy probe (Figure 13), which is carefully introduced and advanced towards the center of the vitreal cavity [78].

3.2. Adnexal tumors

The CO_2 laser can also be used to excise focal SCC from the eyelids or nictitating membranes of horses (Figures 14 and 15). The same can be said for periocular sarcoids [64, 79].

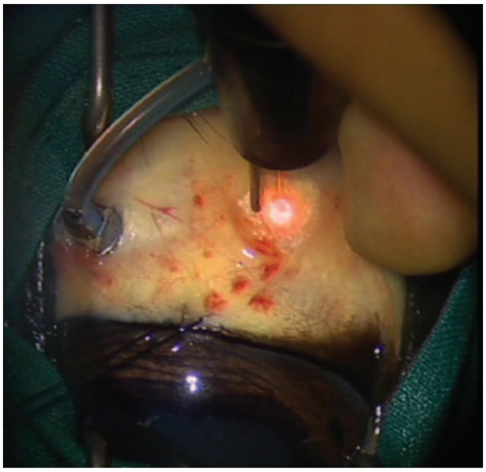

Figure 13 CO_2 laser sclerotomy during a pars plana vitrectomy in a horse. The irrigation port (left) has already been installed.

The lowest effective energy levels should be used in order to avoid excessive carbonization of surrounding tissue. Usually several sweeps are necessary to separate tissues.

4. Nd:YAG laser

Posterior capsular opacification (PCO) is a frequent complication of cataract surgery in animals and people. With improved surgical technique, the use of viscoelastic materials, and new designs of intraocular lenses (IOL), the incidence of PCO has been reduced. However, it still occurs and is potentially blinding. With the Nd:YAG, laser holes can be opened in the opacified lens capsule without the need to reopen the eye. The laser energy can be delivered through the clear cornea and the IOL. The canine posterior lens capsule is less elastic than that of the human eye and does not retract as easily. Consequently the success rate is lower than in humans. In a series of 33 dogs the success rate, as assessed by increased clarity of the lens capsule, was 75%. The average canine PCO requires 75 bursts of 40 mJ each to open the capsule, while in humans only 8–10 bursts of 1–2 mJ are necessary [12, 80].

Figure 14 Squamous cell carcinoma of the third eyelid in a horse.

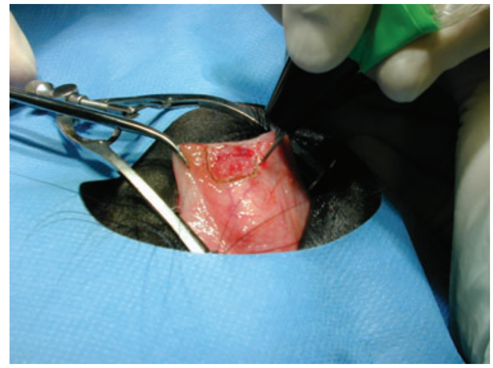

Figure 15 Excision of a circumscribed squamous cell carcinoma by use of the CO_2 laser.

5. Conclusion

Medical lasers have many uses in human and veterinary medicine and surgery. Laser technology has evolved over time and new concepts and units have emerged. The future will see an increase in the lasers used in veterinary ophthalmology and the number of diseases and conditions amenable to this treatment modality.

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