Effects of Argon and Krypton Laser on Experimentally Detached Retinas

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SUMMARY

Krypton and argon laser photoocoagulation on the foveas and blood vessels of experimentally detached monkey retinas were studied clinicopathologically. In this manner heat transmission from the retinal pigment epithelium (RPE) to the overlying sensory retina was avoided.

Krypton lesions bypassed the sensory retina on every occasion to produce major photoocoagulative effects at the level of the RPE and choroid. Argon laser wavelengths damaged the overlying retina in the foveal areas as well as in perivascular structures. Although the krypton laser appears preferable for treatment of macular diseases, proper parameters should be used to avoid serious complications.

Argon laser photoocoagulation is presently an accepted modality of treatment for various retinal disorders. However, due to the deleterious effects of argon wavelengths (488 and 514.4 nm) in the macular area, other modalities of therapy, such as the krypton laser (647.1 nm wavelength) have been advocated for this region.1-3 Recent clinicopathologic studies comparing the effects of argon versus krypton laser photoocoagulation to the retina have shown that krypton laser produced less damage to the inner retinal layers and more damage to the choriocapillaries than the argon laser.2,3 These experiments were performed on attached retinas, where laser energy is first absorbed by the pigment epithelium and is then transmitted to the overlying sensory retina. For this reason, it has been difficult to differentiate the direct effects of laser radiation on the sensory retina. The present study was performed to evaluate the changes of argon and krypton lasers on the foveas and blood vessels in experimentally detached retinas of cynomolgus monkeys. To the best of our knowledge no previous histopathological studies comparing the effects of argon and krypton lasers in detached retina of humans or animals have been reported.

MATERIALS AND METHODS

Experimental Model: Twelve eyes of seven adult cynomolgus monkeys were used in this study. The animals were anesthetized with intravenous administration of 2.5% thiopental sodium (Sural). A specially made blunt-tipped glass pipette that is less than 25 microns in diameter was introduced through the pars plana into the subretinal space under biomicroscopic visualization (Figure 1). Then 0.2 to 0.5 ml of balanced salt solution was gradually injected in the subretinal space. The detachment of the retina involved either the entire macular area or the region around the temporal arcade (Figure 2). After removal of the pipette, hypotony was prevented by tight wound closure.

Laser Source: We used a laser model (Laser-Tek Co, Helsinki) that can deliver up to 5.9 Watts of argon and 1.2 Watts of krypton laser energy through a single slit-lamp delivery system. The krypton laser emits a monochromatic beam with a wavelength of 647.1 nm, whereas the argon laser gives out a beam with major wavelengths of 488 and 514.5 nm.

Methods: After the production of the detached retinas, the animals were immediately subjected to argon and krypton laser photoocoagulation using equal settings. Foveal lesions were produced using a 50 or 100 micron spot size; coagulation time was 0.2 to 0.5 second, and the energy level was 300 to 500 mW. The retinal blood vessels were coagulated using a 200 to 500 micron spot size and 500 to 1000 mW of energy, for 0.2 to 0.5 second. Following laser treatment and after fundus pictures and fluorescein angiography were obtained, the animals were sacrificed and their eyes enucleated. The enucleated eyes were immediately fixed in 4% buffered glutaraldehyde. Individual lesions were dissected with the aid of a dissecting microscope, postfixed in Dalton’s chrome osmium fixative, dehydrated in alcohol, and embedded in epoxy resin. Serial sections were cut to 1 to 2 microns thick and stained with

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toluidine blue. These serial sections were examined by light microscopy. The widest diameter of damage was considered to represent the center of each photocoagulation lesion. In approximately 30% of the histopathologic specimens, the sensory retina detached from the retinal pigment epithelium during processing. In these cases, separate embedding was required.

RESULTS

Foveal Areas: In all cases the argon lesions produced an intense whitening of the inner retinal layers. However, the krypton lesions appeared clinically weaker or invisible (Figure 3). Fluorescein angiography showed extensive early choroidal leakage from both the argon and krypton burns, even when the krypton lesions were not clinically noticeable (Figure 3). In later stages, fluorescein gradually filled the entire detached areas.

Histopathologically, argon wavelengths produced damage to the inner and outer retinal layers (Figures 4 & 5). The ganglion cells appeared swollen and vacuolated. Occasional breaks were observed on the inner limiting membrane. The inner nuclear and outer nuclear layers demonstrated irregularly dense pyknotic, shrunken nuclei. The surrounding inner and outer plexiform layers were also swollen and had clear, watery, disrupted cytoplasms. Photoreceptor outer segments were diffusely irregular throughout the detachment, but, on the photocoagulated area, some were distinctly round and densely stained. At times the entire fovea was necrotic (Figure 5). The retinal pigment epithelial cells showed focal coagulative necrosis and focal areas where cells were absent. Bruch's membrane was intact in every case.

Krypton coagulation of the fovea did not involve the detached sensory retina histopathologically (Figures 6 & 7). However, the lesions demonstrated coagulative necrosis and total disruption of retinal pigment epithelial cells, with rupture of Bruch's membrane. Small amounts of hemorrhage and fibrous exudates were seen in the subretinal space. The underlying choriocapillaries were partially interrupted and occluded (Figures 6 & 7).

Blood Vessel Coagulation: Argon wavelengths produced an intense whitening of the retina, with marked spasm of the vessel (Figure 2). Krypton laser coagulation showed either no clinically visible retinal or choroidal reaction or, when a higher power setting was used, heavy choroidal lesions. Frequent choroidal hemorrhage was observed when a high power or small spot size was utilized with the krypton laser. The retinal vessels with this later modality were never affected when the retinal detachment was not shallow (Figure 2). Histopathologic studies (Figures 8-10) confirmed these observations.

COMMENTS

Until recently, argon laser photocoagulation has been the therapeutic choice for various retinal and choroidal disorders. We created an experimental model that closely resembles a serous detachment of the sensory retina in humans. We evaluated the clinicopathologic effects of argon and krypton lasers on various retinal structures, while eliminating heat transfer from the energy absorbed by the pigment epithelium. Argon lesions produced extensive sensory retinal damage in the foveal area. The krypton laser did not affect these structures; its damage...
was localized at the level of the retinal pigment epithelium and its underlying tissues. Similarly, the absorption of argon laser wavelengths by hemoglobin produced extensive perivascular and nerve fiber layer necrosis, whereas krypton wavelengths bypassed the sensory retina and blood vessels to produce its major photoagulation effects at the level of the retinal pigment epithelium and choroid. The clinical implications of the present study is that the red beam of krypton laser photoagulation may be preferable to argon laser for treatment of macular diseases.

The intraretinal damage produced in the foveas with the argon wavelengths is presumed to be the result of absorption of laser light by the luteal pigment. This pigment, which is present in humans and in nonhuman primates including cynomolgus monkeys, as used in this study, has an absorption within the 400 and 525 nm spectra, which falls within the range of the 488 nm of argon blue wavelengths.

The argon laser used in this study is composed of two components, the blue wavelength of 488.2 nm and the green wavelength of 514.5 nm. We did not evaluate the effects of these components separately because the majority of presently available lasers do not separate these beams. While the blue light is completely absorbed by xanthophyll pigments, only 15% of the green is absorbed by...
this pigment. However, both the blue as well as the green wavelengths are absorbed by hemoglobin; as a result, effects on the retinal vessels and on the perivascular retinal tissues should be similar. The effects of the red krypton light on blood vessels in detached retinas confirmed previous findings that krypton wavelengths did not damage perivascular tissues. This sparing of blood vessels might also be of importance in coagulating close to the fovea, where occlusion of the foveal blood supply could prove detrimental for central visual acuity.

The monochromatic red beam of the krypton laser bypasses important retinal structures, because its major coagulation effect is on the retinal pigment epithelium and choroid. In cases of subretinal neovascularization, because the neovascular tissue is adjacent to the pigment epithelium and originates from the choroid, these vessels can be effectively coagulated with the krypton laser. In clinical
FIGURE 7: Top and Bottom. Krypton laser lesions of Figure 3, left. There is a large break on Bruch’s membrane with tissue necrosis and surrounding subretinal hemorrhage of choroidal origin (black arrows). The inner retinal layers are grossly uninvolved by laser wavelengths. GCL indicates ganglion cell layer; INL, inner nuclear layers; asterisk, shallowed serous detachment in subretinal space. Black and white arrows point to exudate on outer plexiform layer. (Mallory’s stain, 1 u epoxy resin sections, Top × 50; Bottom × 210).

situations, krypton laser coagulation may diminish extensive nerve fiber layer damage and foveal necrosis obtained with argon laser photocoagulation. Moreover, dense or absolute scotomas may be prevented or minimized when proper parameters are used.

Frequent choroidal hemorrhages complicating krypton laser photocoagulation when high energy is used have been previously described. Peyman et al. have found that, in cynomolgus monkeys, by using a low power setting and long exposure time (more than 0.35 second) and/or choosing a large spot size (200 to 500 microns), this complication can be prevented. These parameters also apply to krypton coagulation on areas of detached sensory retina.
REFERENCES


FIGURE 9: Histopathologic changes of argon laser on blood vessel of superonasal arcade of Figure 2. Top. Photo at top shows extensive perivascular damage on nerve fiber layer (NFL) and inner plexiform layer (IPL). GCL indicates ganglion cell layer. Bottom, focal area of retinal pigment epithelium vacuolations and pigment dispersion (arrows). Blocks were embedded separately and were the result of multiple serial sections (Mallory's stain, 1 u epoxy resin sections; Top. X 210; Bottom. X 210).

FIGURE 10: Histopathologic effect of krypton laser photocoagulation on blood vessel. Top, note total coagulative necrosis of retinal pigment epithelium, choriocapillaries, and choroid (white arrows). Nerve fiber layer (NFL) and surrounding perivascular retinal tissues were spared in spite of the shallowness of the detachment. Bv indicates blood vessel (Mallory's stain, 1 u epoxy resin section; X 82). Bottom, at higher magnification, choroid shows extensive coagulative heat damage with necrotic, shrunken, distorted blood vessel remnants (black arrows) and free red blood cells. Note that the damage is so extensive that it reaches the sclera. LPCN indicates long posterior ciliary nerve (Mallory's stain, 1 u epoxy resin section; X 210).