Studies on intravitreal blood vessels.  
III. Effectiveness of intraocular diathermy on blood vessel closure; a comparison with argon laser

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The effect of intraocular diathermy on the closure of intravitreal vessels was studied in a new experimental model and compared with previous studies on argon laser photocoagulation. Intravitreal vessels could be closed easily with diathermy regardless of size or type of vessel. Complete occlusion occurred in 60 per cent of treated vessels and partial occlusion of the vascular tree occurred in an additional 20 per cent. The rate of hemorrhage was 20 per cent. Most hemorrhages were less than one-half disk diameter in area. Diathermy appears indicated in areas in which a background reaction might be damaging or the vessels are surrounded by excessive amounts of glial tissue or when the media is opaque.

Key words: radiofrequency, diathermy, coagulation, intravitreal vessels.

Argon laser photocoagulation is presently the principal treatment for intravitreal neovascularization. Although a valuable method of treatment, argon laser photocoagulation does have limitations. It is often ineffective for treating vessels in areas of fibrous tissue or when opacities exist in the media. A recent study showed that treatment of epipapillary and peripapillary neovascularization with argon laser often did not achieve closure and that intravitreal hemorrhage was a significant complication. Also, the optic nerve is extremely sensitive to direct coagulation.

Recently developed intraocular diathermy has been proposed for treatment...
of intravitreal vessels in which argon laser was not effective.\textsuperscript{4,5}

This study was performed to evaluate the effectiveness of intraocular diathermy in closure of intravitreal vessels using a new experimental model.\textsuperscript{6}

Material and methods

I. Production of intravitreal vessels. Thirty albino and pigmented rabbits, each weighing 2 to 3 kilograms, received intravitreal injection of 15 mg. of NH\textsubscript{4}Cl as previously described.\textsuperscript{6} The animals were observed at the end of a 3- to 4-week period by direct ophthalmoscopy. Only animals with undamaged nasal or temporal vessels, which were free of retinal tissue in at least one eye, were used. Fifteen animals initially injected were selected.

II. Diathermy. (A) Instrumentation. The radiofrequency (RF) infusion probe has been described in detail previously.\textsuperscript{4} The dismantled metal probe and plastic handle are shown in Fig. 1. The core of the metal probe is a platinum wire that delivers energy from the RF unit to a point within the eye; this wire is insulated throughout its length except at the tip where coagulation takes place. A tube concentric to the platinum wire permits the infusion of saline with a plastic tube connecting an infusion system to the inlet port on the probe. This probe fits into the plastic handle shown in Fig. 1. Diathermy application is controlled by a switch on this handle.

Fig. 2 shows the infusion system for maintaining intraocular pressure. A 5 c.c. syringe filled with 200 micrograms per milliliter of solution of gentamycin in normal saline will accomplish infusion slowly and accurately.

The generator used for radiofrequency in this experiment was a Cameron Miller diathermy unit.

(B) Materials and methods. Fifteen albino rabbits were anesthetized and their pupils were dilated as previously described. A temporal canthotomy was performed and the conjunctiva was separated from the sclera at the limbus. The inferior and superior rectus muscles were then isolated and tied with 4-0 silk to provide a stabilizing mechanism while a flaringa ring was sutured to the eye. The ring, slightly larger than the corneal circumference, was sutured with 8-0 silk to the sclera. The sutures were placed in the episclera and did not penetrate the entire scleral thickness. After the ring was thus secured, the sutures on the inferior and superior rectus muscles were tied to the ring.

A small sclerotomy was then performed on the temporal pars plana and encircled by a single row of diathermy applications and a single mattress suture placed through the lips of the sclerotomy. Punchure with a 22-gauge needle allowed insertion of the hand-held diathermy probe. Infusion through the microliter system was then started to restore intraocular tension. After tightening the
sclerotomy suture around the probe, the probe was directed within the eye with the aid of a slit-lamp operating microscope and a low-vacuum contact lens.

Under direct vision, the probe was advanced near the vessels and coagulation performed with the minimal amount of energy necessary to achieve segmentation. Two rows of segmentation one disk apart were made across the entire area of intravitreal vessels.

The probe was then withdrawn. The mattress suture was closed during constant infusion. The ring was removed and the conjunctiva and lids sutured back in place with 5-0 catgut. Fundus photographs of these vessels were taken before and after this procedure. The eyes were observed for one week, after which fluorescein angiography was performed.

III. Histology. Animals in which intravitreal vessels were coagulated by radiofrequency and were found closed by fluorescein angiography were killed. The coagulated vessels were studied by electron microscopy.

Tissue to be examined by electron microscopy was immediately immersed in one per cent formaldehyde, one per cent glutaraldehyde mixture in phosphate buffer (pH 7.35), postfixed with Dalton's Chromic Osmium for two hours, again washed in phosphate buffer, dehydrated in graded ethanols and propylene oxide, and embedded in araldite.

Thin sections were cut on an LKB ultramicrotome, stained with uranyl acetate and lead citrate, and examined with a JEM 100B electron microscope.

Results

Intraocular diathermy coagulated intravitreal vessels in 15 rabbits. Coagulation of these vessels was possible using energy levels of 0.4 to 0.8 on the Cameron Miller diathermy unit. The size or type of vessel did not affect the amount of energy necessary to achieve coagulation. If coagulated tissue adhered to the tip of the probe, however, it was necessary to withdraw the probe and remove this tissue, as further coagulation became more difficult and
higher energies were needed if this coagulum was not removed. The vessels usually coagulated in a few seconds if a coagulum did not form on the tip. A fundus photograph taken at this time demonstrated the appearance of the vitreal vessels immediately after coagulation (Fig. 3). The area in which the probe was swept across the vessels can be easily seen.

It was possible to maintain intraocular pressure with the infusion system during coagulation and during insertion and removal of the probe. Closing the mattress suture after removal of the probe prevented any further escape of fluid. The treated vessels in all but one animal were closed immediately after coagulation. This animal developed an immediate hemorrhage to be described later. Of the 14 successfully coagulated animals, the vitreal vessels in two animals had completely opened at the end of one week. In four other animals, some branches of the coagulated vessels were open one week later. However, the majority of the vessels coagulated in these four animals remained closed. In the remaining eight animals, the vitreal vessels remained completely closed as demonstrated by fluorescein angiography (Fig. 4). The blockage of dye can be seen at the areas of coagulation. Leakage of dye proximal to the treated area was evident during fluorescein angiography performed immediately after coagulation.

Intraocular hemorrhage occurred in three animals. In one case it occurred during the operative procedure; a coagulum had formed between the probe and vessel
wall when the probe was removed. A fundus photograph showed the extent of the hemorrhage (Fig. 5). In two other animals, a small area of bleeding from the coagulated vessels was noted the day after treatment and estimated to be $\frac{1}{4}$ to $\frac{1}{2}$ disk diameters in size. Coagulation by radio-frequency was independent of opacity of the media.

Histologic examination revealed that vessels that remained closed at the time of fixation all contained closely packed erythrocytes within the lumen (Figs. 6 and 7). The lumen of coagulated vessels also contained small plasma bubbles and platelet-like structures (Fig. 7).

In the area of direct coagulation, coagulative necrosis of the vessel wall occurred (Figs. 7 and 8). Distal to this area, degeneration of the endothelial cells was evident (Fig. 6). In many sections of diathermy-treated vessels, macrophages were in close proximity to the vessels and phagocytosis was also frequently evident (Fig. 9).

**Discussion**

In contrast to the laser-treated vessels, coagulation with a radio-frequency probe was not influenced by size or type of vessel. It was possible to achieve immediate coagulation of both large and small arteries and veins. Cataract, of course, would not affect coagulation with radio-frequency unless it prevented visualization of the intravitreal vessels.

Coagulated vessels reopened in diathermy-treated animals as in previous experiments with argon laser. In dia-
therapy-treated animals the vessels in 60 per cent of the treated eyes remained completely closed and in an additional 20 per cent only a small portion of the total vascular tree reopened.

Diathermy caused hemorrhage in 20 per cent of animals treated. In all but one case of intraocular diathermy, the area of hemorrhage was small, less than one-half disk diameter. In the exception, a large hemorrhage covering approximately one-fourth of the fundus was produced during intraocular diathermy when the vessel walls were accidentally torn. In previous experiments, argon laser treatment of vitreal vessels caused an 18 per cent rate of hemorrhage. It appears that the rate of vitreous hemorrhage was not significantly affected by method of treatment, although each method could produce large hemorrhages. During the diathermy, the vessel wall could be torn, and during argon laser coagulation a large hemorrhage could result from the use of a high-energy level during coagulation of vessels accompanied by fibrous tissue.

Background reaction is, of course, not a consideration with radiofrequency but is present with argon laser.

Histologic examination of coagulated vessels shows very little difference between coagulation by diathermy and argon laser.7 The vessel lumen completely fills with coagulated red blood cells. Vessel wall damage is generally more severe with diathermy, but in each case this damage decreases in proportion to the distance from the point of coagulation. In the sections taken from each area of coagulation we could not demonstrate fibrin or a true platelet plug, signs of frank intravascular coagulation were absent. How-

Fig. 8. Electron micrograph of central portion of the lesion of a diathermy-treated vessel exhibiting a large fibrinoid necrotic area (N). Note characteristic "clumping" or erythrocytes (E) and loss of cellular fine detail in degenerative nucleus and cytoplasm of cell (c) in close association with an area of erythrocytes. (×5,833.)
Fig. 9. Electron micrograph showing phagocytosis of an erythrocyte (E) by a macrophage in diathermy-treated tissue. (x9,050.)

However, in rare instances there were inclusions that appeared somewhat similar to platelets (Fig. 7). Because of density variation in these inclusions, it was uncertain whether or not these were true platelets. Thus, the mechanism of intravascular coagulation by diathermy or argon laser appears independent of the physiologic clotting mechanism. It appears that closure is secondary to direct effect of heat on the cellular and plasma proteins causing coagulum formation.

In many sections, migration of macrophages from the vitreous was visible. Phagocytosis of red blood cells could be demonstrated. We assume that these cells are stimulated by factors released during tissue damage to the vessels.

Treatment with argon laser is, of course, always preferable to diathermy when both are equally effective. Diathermy, being an intraocular surgical procedure, carries the risk of direct mechanical damage to the lens or retina and the possibility of producing direct intraocular infection, factors that are not present with argon laser. This study purposed to define the circumstances under which each method may be useful. When small arterioles are coagulated or when an opacity exists within the media, treatment by argon laser may not be effective. Fibrous tissue formation within the vitreous, depending upon its location in reference to the vessel coagulated, can greatly increase the energy necessary for coagulation with argon laser and also the risk of hemorrhage. In areas in which a background reaction might be damaging, diathermy may be most appropriate.

REFERENCES
