Electrovitreotomy

2. Principles and results

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A clinical trial on electrovitreotomy involving seven persons who had a variety of serious problems was undertaken between December 1968 and January 1970 with the Vitritron (from vitreous, electron), a suitable electrodissection device (O'Malley and Heintz, 1973).

Proliferative and vasoproliferative vitreous strands and membranes caused by diabetes and congenital malformation were divided readily and completely without bleeding, but we were unable to cut slack clear vitreous strands or gel of ordinary consistency and tension. Vitrectomy was not effective unless the otherwise cuttable structures were free of gel and surrounding liquid, and were not contaminated by dispersed blood or pigments.

The tissue limitations of electrovitreotomy were seldom identifiable with reasonable surety before surgery. As no means for coping with vitreous of ordinary consistency and tension *via* a pars plana approach was available to us at that time, electrovitreotomy was abandoned temporarily until we had developed the Vitritome (O'Malley and Heintz, 1972), an alternative vitrectomy device of the cut-and-suck genre (Machemer, Parel, and Norton, 1972).

Vitrectomy with the Vitritome was found to be a clinically suitable complement to electrovitreotomy with the Vitritron as the advantages of one were largely the limitations of the other. While normal and abnormal vitreous with a wide range of consistency, tension, and clarity could be removed with the vitrectomy device, tense or firm forms were not always amenable to severing by piecemeal excision as they would not always mould and become engaged in the cutting port.

To describe our overall experience with electrovitreotomy requires details of the anatomy, pathology, examination, and natural history of a variety of vitreo-retinal and vitreous maladies as well as viewing and illuminating systems suitable for diagnosis and surgery, hand aids, hand substitutes, and vitrectomy instrument systems.

This account describes the basic clinical features

of electrovitreotomy and the underlying thermoelectric and tissue factors, and principles.

INSTRUMENTS

An instrument suitable for electrovitreotomy is collectively called the Vitritron from the words vitreous and electron; several types of generators, cords, electrodes, insulation, etc., have been used. Electric power is, for the present, adequately provided by the vacuum tube settings, the so-called number one 'cutting' current of a conventional Bovie electrosurgical generator. The Vitritron has a fine lightweight handle and a pliable cord at the anterior end to reduce drag. Clinical problems associated with unintended coagulation and the marked tendency for stainless steel and a variety of insulating materials to disintegrate have been partly remedied by substituting an 0.1 mm platinum-rhodium wire, spraying the entire shaft with an insulating Teflon to give an outside diameter of 0.2 mm: 0.1 mm of the insulation at the tip is removed to achieve the desired highly concentrated electrical effect that characterizes electrodissection in general and electrovitreotomy in particular.

The potential for freehand intraocular surgery with an indirect ophthalmoscope and conventional instruments is markedly limited, mainly because of paradoxical imaged motions in the equatorial plane. The design and choice of the Vitritron materials specifically favour more precise freehand (as opposed to micromanipulative (Peyman and Dodich, 1971)) intravitreal electrode control. It is a flexible way of achieving good illumination and viewing with a minimum of equipment—that is, by microscope and contact lenses—without precluding the use of these devices when needed.

Operative technique

The operations followed a general pattern previously described (O'Malley and Heintz, 1973).

The opening in the sclera, pars plana, and vitreous base was made with a sharp 25 gauge needle (outside diameter 0.5 mm) to permit ready insertion of the relatively blunt electrode (outside diameter 0.22 mm). Leakage of liquid on withdrawing the electrode was easy to control by moistening the sclera at both ends of the groove and shrinking it slightly with diathermy or

cautery (under saline if the cautery tip became too hot). Prolapsed uvea or vitreous was amenable to repositing or excision.

SURGICAL EXPERIENCE

Altogether 22 people, 11 male and 11 female, between 6 and 73 years of age were examined at regular intervals during the 2 months to 5 years that had elapsed since they had had electrovitreotomy.

One diabetic woman died from chronic renal failure, and another died because of coronary occlusion about 1 year after vitreous surgery.

All 22 patients had a single electrovitreotomy—11 as the sole procedure, 11 in combination with vitrectomy, four with lens extraction, and three with a scleral buckling—for various vitreous afflictions caused by trauma, diabetes, Eales's disease, retinal vein branch occlusion, vitreous prolapse, and congenital malformation.

This study confirmed our initial findings (O'Malley and Heintz, 1973) that some intravitreal structures are amenable to electrodissection using this method and some are refractory. We were consistently unable to cut human vitreous of ordinary consistency and tension in mass, membrane, or strand form.

The following pathogenically taut vitreous forms have been divided in 17 patients:

1. Vascular and avascular fibrous bands and membranes (12 cases) (Figs 1 and 2)
2. Residual clear vitreous strands that were relatively refractory to vitrectomy by the suck and mechanical cut method (4 cases)
3. New vessels providing they were without fibrous tissue either on, or attached to, clear vitreous (4 cases)
4. Compact stalk-shaped adhesions with a core of gel traversing a fluid-filled space (1 case).

The breakdown of cases per pathological form exceeds 17 as four patients had multiple types of dissectable lesions. Seven patients have had treatment for 6 months to 5 years, four received electrovitreotomy, three received electrovitreotomy plus vitrectomy.

Electrovitreotomy has been found helpful for the following clinical problems:

1. Recurring vitreous haemorrhages that are beyond the reach of argon laser photocoagulation, where vitrectomy is not yet justified
2. Traction detachment of the retina which would not benefit by scleroplastic procedures, nor yet justify a scissors vitrectomy or vitrectomy
3. As a complement to vitrectomy for relaxing traction detachment and numerous fixed folds due to short dense bands which were inaccessible to or extremely hazardous using other cutting modalities.

Considerable free blood in the vitreous cavity did not necessarily preclude using this method without vitrectomy. Resting the eye in an appropriate position for some hours would cause freely mobile blood and blood elements dispersed in liquid to form a sediment and permit the fundus to be seen for evaluation and electrovitreotomy without vitrectomy.

The following case is described at length to illustrate many of the clinical features that distinguish this type of procedure (Fig. 3).

A 35-year-old woman, insulin-dependent since the age of 10 years, had gross recurring vitreous haemorrhage in the left eye, with an oval heavily vascularized proliferative membrane on the posterior aspect of the grossly retracted condensed vitreous. The membrane had a surface area of approximately 12×10 mm and a broad moderately deep trough-like configuration, a relatively narrow stalk-shaped adhesion to the entire surface of the disc and adjacent 12.0 o'clock retina, a

FIG. 1 25-year-old woman with severe macular distortion, right eye, due to a dense traction band extending from the vitreous base, grossly scarred between 4.30 and 9.30. Vision reduced to 20/400 with eccentric fixation since parasitic vitreous inflammation at age 6 years. Left, avascular vitreous band before electrovitreotomy. Right, cut stump 1 year after electrovitreotomy. Vision improved to 20/100 with central fixation

FIG. 2 55-year-old woman with complicated, break induced, retinal detachment due to long-standing occlusive vascular process. Left, a tense roughly triangular retina-to-retina vascular membrane causing fixed retinal folds. Right, the same membrane divided electrically with relaxation of traction folds

second narrower adhesion to the retina half way between the disc and the 1.0 o'clock equator. Many large new vessels were feeding the membrane *via* both adhesions. There were two traction detachments of the retina, measuring 1 disc diameter at the posterior and 3 disc diameters at the anterior vitreo-retinal traction site, a dense linear condensation of blood behind and adjacent to the posterior border of the vitreous base from 4.30 to 8.00 on resting, 4 red cells (on the same 1 to 4 scale commonly used for estimating free cells in the anterior chamber) were dispersed in the retrovitreal space on sitting upright, 1 red cell in the otherwise clear vitreous gel, and minimal background retinopathy. Her best correctable visual acuity in remissions was 20/60. She was not a suitable candidate for argon laser photocoagulation.

With facilities for carrying out a vitrectomy at short notice, electrovitrectomy without vitrectomy was performed *via* a pars plana opening at 6 mm from the corneal limbus at 3.30 o'clock. The connexions between the vasoproliferative membrane and the ocular wall were severed electrically by dividing its oval form at a right-angle to its long axis, allowing both cut edges to retract forwards somewhat like a drawbridge, exposing the attachments to the disc and retina which were then cut to allow the entire malformation to move forwards. Iatrogenic traction caused a haemorrhage with clot formation at the disc. This was a result of manoeuvres to cut the attached tense vitreous with an uncurved electrode at an angle unfavourable to the sclerotomy position. The bleeding was quickly and effectively controlled merely by raising the intraocular pressure by digital compression while observing the fundus. The haemostasis was verified by watching for a further 30 minutes.

The intravitreal manipulations, from sclerotomy to sclerotomy, required between 10 and 15 minutes. In the

6 months since the ocular surgery she has had no recurrence of haemorrhage, the residual blood has cleared, the traction features of the disc and retina have disappeared completely, and visual acuity has improved to 20/20 with correction without overt new retinopathy.

Complications

While the prevalence and severity of complications has notably declined with practice, six major and eight minor problems arose regarding incision, iatrogenic traction, and electrocoagulation:

Migration of pre-existing free blood into the electrode tracts in the vitreous body (1 case).

Vitreous incarceration into the pars plana and sclerotomy (1 case).

Iatrogenic clot adhering to vitreous-to-retina and vitreous-to-disc adhesions (3 cases).

Retinal tear (1 case).

Electrocoagulation of the sensory retina contributing to an immediate tear (1 case).

Coagulation of the sensory retina with a subsequent atrophic hole (2 cases).

Occlusion of a branch of the central retinal vein (1 case).

Opacification of the vitreous gel (4 cases).

Coagulation complications were potentially serious. Freshly coagulated sensory retina is very friable and prone to tear with pathological and iatrogenic traction.

With care, practice, and favourable structures it has been possible to perform electrovitrectomy as close as 0.5 mm to the retina or avulsed vessels without apparent ill-effect. To avoid retinal dia-

(a)

(d)

(b)

FIG. 3 35-year-old diabetic woman with gross recurring vitreous haemorrhage, in remission. Visual acuity was 20/60

(a) 12 × 10 mm vasoproliferative membrane on posterior aspect of detached vitreous

(b) Tense vitreous adhesion to disc and adjacent detached retina

(c) Retracted upper half of membrane after electrovitrectomy. Note the atrophy of the occluded, mobilized new vessels

(d) Disc area after division of vitreous adhesion

(e) Mid-peripheral vitreo-retinal adhesion site is smooth 6 months after release of vitreous traction. Note residual diabetogenic retinal and vitreous scars

(c)

(e)

thermy and occlusion of branches of the retinal vein and artery utmost caution concerning dial setting, insulation, time factor, electrical character of target, and adjacent tissue was mandatory.

Clusters of minute opaque sphere-shaped coagulations of clear vitreous were noted in four cases (Fig. 4). Fortunately, these coagulation lesions have not been associated with observable progression or causally relatable opacification, fibrosis, vascularization, shrinkage, retraction, or condensation of adjacent or remote vitreous.

The electrode is so pliable that intact retina and normal retinal vessels were undamaged by careful vitreous manipulation and direct contact. New vessels were very prone to bleed with relatively little direct or indirect force. Bleeding during surgery was potentially critical. Fresh blood tends to obscure the target tissue with an opaque clot that insulates it against further electrodissection. Further attempts with greater electrical force are mechanically and electrically hazardous. Fortunately traction-induced bleeding can be minimized by the proper choice of the sclerotomy site, configuration and handling of the electrode, and pressure-induced haemostasis at the first sign of haemorrhage. Active bleeding is readily controlled by raising the infusion pressure or by simple manual or digital compression of the globe.

Surgical efficiency and safety increased with the length and glial content of the stalk. They decreased with the number, area, and peripheral location of the vitreo-retinal adhesions, the height to which retina and avulsed vessels were displaced, and the degree of medial opacity. The profile presented by the target structure is important as traction complications are potentially grave.

Comment

To perform electrovitrectomy with relative safety and benefit calls for a pragmatic application of the principles of electrodissection. The would-be electrovitrectomy surgeon should heed the following cautions.

Electrovitrectomy, like electrodissection in general, is performed by passing a current of suitable density through a suitable electrode while rapidly stroking the tissue without attempting to cut, press, or deflect it. It does not sever by any mechanical agency such as sharpness of the tip or hand pressure. Instead an electrical arc ahead of the moving electrode volatilizes a very narrow zone with such a complete breakdown of the morphological elements that tense structures cleave open.

It may be helpful to compare electrocutting with diathermy, the more familiar form of electrosurgery.

The goal of surgical diathermy is to induce a degree of heat-dependent tissue coagulation which

FIG. 4 67-year-old aphakic man with right retinal detachment due to gross vitreous prolapse and refractory to radical scleral buckle. Note two small clusters of minute unchanging coagulations of clear vitreous remnant, seen by retroillumination at 6 o'clock border of pupil 6 months after combined vitrectomy and electrovitrectomy. The vitreous opacity at 1 o'clock existed before vitreous surgery. The retina is reattached

promotes the clinical objective: irritation to provoke a subsequent bond (chorio-retinal scleral adhesions): shrinkage to close blood vessels firmly and permanently or to contract sclera (to create relative buckling or to close small linear sclerotomies): necrosis (tumour destruction): charring (tumour). In general diathermy factors include a relatively low heat density spreading for a few seconds over an area of tissue from an electrode which is almost invariably held motionless.

In essence electrodissection is a series of tissue explosions of microscopical dimensions capable of interrupting the physical continuity of the living tissue. Its interrelated causal factors include a relatively high heat density at a point immediately adjacent to the tip of a fine moving electrode for a period in the order of a thirtieth of a second.

Tissue effects of both forms of electrosurgery are heat dependent. According to Joule's law, the heat density (W) adjacent to the electrode is a product of the square of the current density (i), the electrical resistance of the tissue (R) and the duration of the electrical action (t), $W=Ki^2 Rt$. K is a constant that can be neglected.

There is a large range of potential electrosurgical tissue effects because these equational factors are very variable. The duration of electrical action at a tissue point (t) may be as long as 5 seconds or more with a motionless electrode (diathermy) or as short as one-

thirtieth of a second when it is moving (dissection). This means that the time factor may vary 150 fold. The electrical resistance of irrigating solutions is 1, blood and liquid vitreous approximately 1, and collagen approximately 3. Thus collagen-rich bands induce approximately three times as much heating effect as for instance water-rich vitreous gel, the resistance of which is probably much closer to 1. The current density (i) varies with the dial setting (0 to 100) and the relative strength of the current dialled (1 to 4 or more), and inversely with the area of the active electrode. In addition the heat at any point other than the immediate vicinity of the electrode declines with the fourth power of the distance. Understandable failure to appreciate and apply these factors as a whole accounts for the lamentable misuse, neglect, and mystery that surrounds these potentially elegant surgical art forms. Consequently the would-be intravitreal electrosurgeon may ignore none of these factors with impunity if he is to perform with acceptable precision, predictability, and safety.

Labelling currents as 'cutting' and 'coagulation' is an additional source of confusion. In spite of the labels it is important to realize that there is no such thing as a 'cutting' current or a 'coagulating' current *per se*. If the electrode is held immobile 'cutting' currents cannot cut. If the electrode is moved appropriately with respect to the tissues a 'coagulating' current can be made to cut.

It is important to distinguish between electrovitrectomy and electrovitrectomy, an additional form of electric dissolution pioneered by Hennig (in press).

To perform electrovitrectomy, vitreous is sucked

into a probe (inside diameter 1 mm) comprising two insulated concentric tubes the bare tips of which constitute a bipolar electrode. The portion of vitreous within the instrument port is liquefied by electrically-induced heat. The free vitreous within the probe is evacuated. Large masses of vitreous of normal composition prolapsed during injury, cataract extraction, and keratoplasty have been removed. Abnormal vitreous bands and membranes of the kind that yield to electrovitrectomy have been unsuitable for electrovitrectomy.

Summary

Continued experience confirms the suitability of electrovitrectomy for dividing pathogenically taut proliferative and non-proliferative vitreous forms with a minimum of bleeding, and an inability to cut vitreous of ordinary consistency and tension. It differs directly with electrovitrectomy in these regards.

To use effectively with a minimum of complications it is mandatory to have a vitrectomy capability immediately at hand and to respect a wide variety of interrelated factors that include: current density, electrical resistance of tissues, duration of electrical action: dimension, insulation, and configuration of the electrode: configuration, tension, location, and morphological content of dissectable structures.

Mobile and dispersed blood in the liquid of the retrovitreal space often surrounds cuttable vitreous lesions. Frequently rest causes it to sediment and improves viewing sufficiently to permit effective electrovitrectomy without vitrectomy.

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