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Review Article

Retinal Detachment Surgery...Past to Future - A Review

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Abstract

The term retinal detachment is used to describe a separation of neurosensory retina from retinal pigment epithelium (RPE). This review article describes past incorrect theories and attempt of treatment and newer advancement in rhegmatogenous retinal detachment surgery.

Keywords: Retinal Pigment Epithelium (RPE); Retinal Detachment Surgery; Neurosensory Retina

Introduction

The history of the diagnosis and management of retinal detachment begins with the invention of the ophthalmoscope by von Helmholtz in 1851. Numerous ingenious, but incorrect, theories of etiology and invention, but misguided, attempts at treatment preceded the postulation of rhegmatogenous theory by de Wecker, Leber and Gonin.

There are 4 era for postulation of rhegmatogenous theory and treatment:

1. The Early era (1851-1918)
2. The Gonin era (1919-1947)
3. The Custodis-Schepens-Lincoff era (1947-1971)
4. The Machemer era(1971-Present).

The early era (1851-1918)

Incorrect theories of etiology:

1. Theory of distension
2. Theory of hypotony
3. Theory of exudation.

Attempts at treatment

A different approach was taken by those who felt that the RD was caused by exudation. The surgeon deliberately slashed holes in the retina to allow the sub retinal fluid (SRF) to pass into the vitreous. Another futile attempt to counteract exudation was the injection of hypertonic (30%) saline under the conjunctiva to draw out the SRF.

Some surgeon attempted to create scars between the retina and pigment epithelium to hold the retina in place. The treatment was not directly at the retinal breaks but was randomly applied in the area of the detachment. Other surgeon tried to suture the retina to the choroid.

On the histopathological examination, Muller found vitreoretinal fibrous band which he felt was the cause of the RD. His finding lead the Deutschmann to postulate that the retina could be reattached only if the vitreous bands were sectioned. He introduce the fine knife into the vitreous and slashed backwards and forwards. They believed that hole would help the retina to settle.

Muller introduced the scleral resection operation in 1903 on the basis of the theory of distension.

The Gonin era (1919-1947)

Rhegmatogenous theory

Coccius was the first to find retinal breaks on clinical examination [1], but de Wecker first suggested that they were the cause of what was then called spontaneous retinal detachment. He felt that liquid vitreous forced holes in the retina. Leber found retinal breaks in 70% of recent retinal detachments and noted that there was nearly always a retinal break in the area where the retinal detachment started. His own clinical and histopathological findings led him to conclude that vitreous traction, caused by degeneration and collapse of the vitreous body, tore holes in the retina. Liquefied vitreous passed through these holes and under the retina, causing the detachment.

It is apparent that at this point Leber understood the etiology of retinal detachment. In 1908, however, influenced more by histopathological than by clinical findings, he abandoned his initial theory in favor of an incorrect one. He now postulated that retinitis stimulated the growth of preretinal membranes which later contracted tearing holes in the retina. He still recognized the importance of retinal breaks in the genesis of retinal detachment, but he now maintained that vitreous degeneration was secondary to RD and not its precipitating factor. It is apparent from drawings that his error stemmed from studying causes of RD with proliferative vitreoretinopathy (PVR).

Ignipuncture (Thermocautery) operation

Jules Gonin, the father of retinal detachment surgery, revived Leber's first theory [2] stressing that contraction of the vitreous body tore holes in the retina. The tears occurred at sites of abnormal vitreoretinal adhesion caused by either previous chorioretinitis or by chorioretinal degeneration. Once Gonin realized that the breaks found in retinal detachment were the cause of the detachment, he knew that a permanent cure depended on sealing them. In 1919, he performed the first operation designed to close the breaks [3]. After careful localization of the break, he made a radial incision down to the choroid with a Graefe knife. The same knife was then used to drain the SRF. Next, a red-hot cautery was inserted 2 to 3 mm into the wound and held in place for 2 to 3 second to ensure that the retina had been directly cauterized (Figure 1A and 1B). It was not until 1929 that the world became convinced that Gonin's operation would cure retinal detachment. Its complication included intraocular haemorrhage and vitreous loss with retina incarceration.

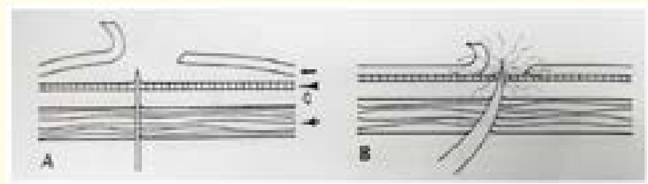

Figure 1: Gonin's operation. A: Drainage of SRF by Graefe knife. Small arrow indicates the retina; arrowhead, the pigment epithelium; open arrow, the choroid, and large arrow, the sclera. B: Coagulation of the choroid by thermocautery.

Gonin had achieved a miracle. Retinal detachment, which had previously been considered inoperable, now had a surgical success rate of 40% to 50%. Gonin's two principles have remained the basis for all successful retinal detachment:

1. All breaks must be found. He emphasized careful clinical examination.
2. All breaks must accurately localized so that they can be sealed by the treatment.

Early improvements in ignipuncture

Guist's operation (Multiple trephination)

Guist trephined out multiple plugs of sclera surrounding the retinal tear(s) and treated the bare choroid with a potassium hydroxide stick [4]. Once the SRF had been drained chorioretinal scars formed and walled off the retinal break (Figure 2A and 2B).

Larsson's operation (Surface diathermy)

When electric current flows in a resistive conductor such as the tissues of the eye, the heat generated causes localized coagulation. Larsson used this principle to surround the retinal break with a firm chorioretinal scar [5]. He found that applications of diathermy (radio frequency electric current) to full-thickness sclera coagulat-

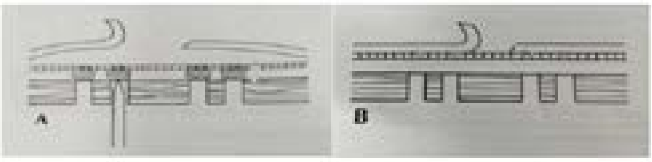

Figure 2: Guist's operation. A: Multiple plugs of sclera have been traphned out to allow cautery of the choroid by potassium hydroxide stick. B: Chorioretinal scars after drainage of SRF.

ed the choroid (Figure 3). Drainage of the SRF then brought the retina into contact with the treated choroid. If no tears could be found he scattered treatment in the area which he felt had detached first.

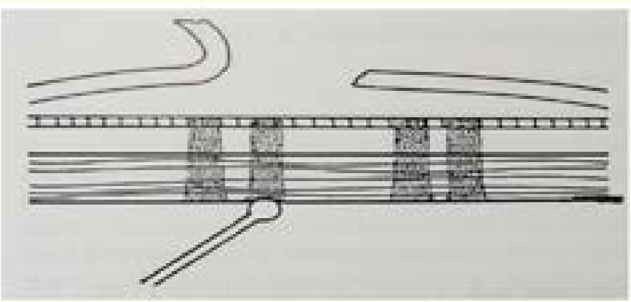

Figure 3: Larsson's operation. Application of full thickness diathermy surround the break.

Weve's operation (Penetrating diathermy)

Weve improved upon Gonin's procedure by substituting penetrating diathermy for heat cautery [6]. A fine needle electrode introduced into the eye coagulated the choroid and the retina. Gonin's procedure allowed only a single application of cautery, whereas Weve's operation made multiple applications of treatment possible. His rate of success was therefore higher because his chances of scaling the break were better. Coagulation of the retina appeared as a white mark which could be observed with an ophthalmoscope and used as a guide in positioning the next penetration. Each time the needle was removed form the sclera, there was some drainage of SRF. The procedure was continued until the tear was completely surrounded by treatment. The major advantage of this procedure was that at the end of the procedure the retinal break was completely treated and no SRF was present. As in Gonin's operation, however, vitreous was occasionally lost and the punctures sometimes produced new retinal holes.

Safar's operation (Simultaneous multiple puncture)

Safar mounted fine needles on small conducting plates [7]. He inserted the needles around the break piercing the sclera, choroid, and pigment epithelium. No needles were removed until diathermy had been applied to all of the plates (Figure 4). Therefore, there was neither premature drainage of SRF nor vitreous loss. When the needles were removed the SRF slowly oozed out. This operation was popularized in the United States by Walker and Pischel.

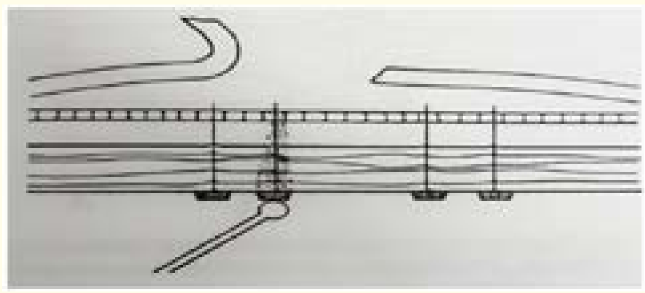

Figure 4: Safar's operation. Diathermy is applied to fine needles which perforate the sclera, choroid and pigment epithelium.

Lindner's operation (Scleral resection)

In 1931, Lindner revived Müller's scleral resection operation, i.e. removal of a full thickness strip of sclera [8,9]. The bare choroid was coagulated by potassium hydroxide (Figure 5). This operation had two theoretical benefits. First, it reduced the volume of the eye so that the retina could more easily fall into place and second multiple holes could be treated. However, the operation was dangerous and difficult. Deep lamellar resection, a safer and easier variation, had been abandoned by Lindner as ineffectual, but Shapland and Paufique revived it as an improvement in the early 1950s. They recognized that this procedure, in which a very thin layer of sclera was left over the choroid had the additional benefit of causing a broad area of inflammation which could treat unseen retinal tears.

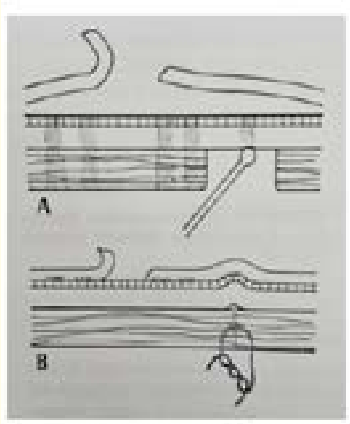

Figure 5: Linder's operation. A: The bar choroid is cauterized by potassium hydroxide after strip of full thickness sclera has been removed. B: The edge are sutured together. Shortening the sclera was the goal of the operation.

The Custodis-Schepens-Lincoff Era (1947-1971)

Instruments for examination

The current high rate of reattachment is due not only to improvements in surgical technique but also to improved methods of ocular examination. Two significant advances in fundus examination were made in the late 1940s. Charles Schepens electrically illuminated binocular indirect ophthalmoscope is, by far, the most valuable instrument currently available for evaluation of the detached retina [10]. Additional important information is obtained with the Goldmann three mirror lens, which permits stereoscopic slit lamp examination of almost the entire retina if the pupil can be widely dilated and the ocular media is clear. It is especially useful for finding small breaks and for evaluating the vitreous. More recently wide-angle contact lenses combined with scleral depression have been found to be useful in patients with small pupils.

Intravitreal air injection

In 1938. Rosengren [11] increased the rate of reattachment by injecting air into the vitreous to tamponade the retinal break after diathermy treatment and drainage of SRF. Postoperatively, the patient had to be positioned so that the air rose against the hole (Figure 6). Using this technique, Rosengren was able to achieve successful reattachment in 76% of his cases [11].

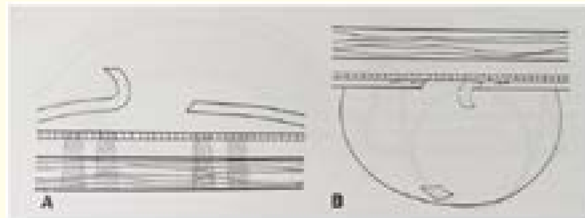

Figure 6: Rosengren's operation. A: Application of full thickness diathermy to surround the break. B: After the drainage of the SRF, air is injected in the vitreous cavity. Air tamponades the break and pushes it towards the choroid.

Scleral buckling explants

In the history of retinal detachment surgery, scleral indentation (buckling, introduced by Ernst Custodis in 1953, is second in importance only to the contributions of Jules Gonin. Custodis called his procedure plombenaufnähung, literally, the sewing on of a seal [12,13]. He first treated all breaks with surface diathermy and then closed them by sewing a polyviol explant (the plombe) onto the overlying sclera. The indenting explant reduced vitreous traction and closed the break, allowing a firm chorioretinal scar to form (Figure 7). Custodis emphasized that the explant must be large enough to close the entire retinal break, since a misplaced explant can keep the break open.

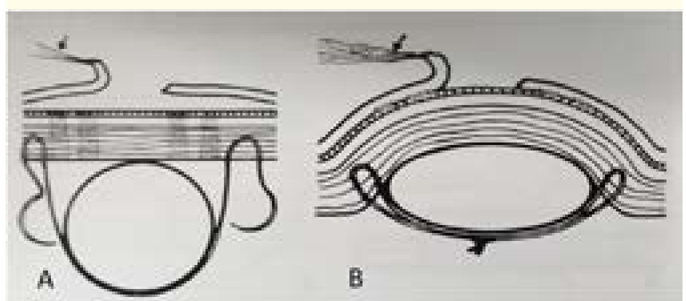

Figure 7: Custodis operation. A: Application of full thickness diathermy to surround the break. Explant and sutures are positioned. Note vitreous traction(arrow). B: The retinal break is closed by the indented sclera. The vitreous traction(arrow) is released.

In addition to permanently reducing vitreous traction, Custodis' explant technique made drainage of SRF unnecessary in many cases. He found that even if the break remained open at the end of the operation, a properly placed and correctly sized explant would result in successful reattachment of the retina He was able to cure 84% of his cases.

A major complication of Custodis' operation was that the surface diathermy caused scleral necrosis. If a reoperation became necessary, it was difficult to place sutures in the thinned sclera. Photocoagulation, invented by Meyer-Schwickerath, eliminated this complication. The explant was placed and either immediately or I to 2 days later, the breaks were treated with photocoagulation. Unfortunately, because xenon arc photocoagulation requires anesthesia, the patient was often subjected to 2 operative procedures. Moreover, successful treatment is dependent upon wide dilation of the pupil, which is sometimes impossible immediately after a SB procedure.

Lincoff made the next major advance in explant technique by adapting cryotherapy for retinal surgery [14]. This was a more benign treatment than its predecessors, as it did not cause scleral necrosis. Lincoff also introduced a soft silicone sponge material for use as an explant, and a spatula needle [15] for safe scleral suturing. His latest contribution is the temporary balloon buckling device [16].

Scleral buckling implants

One of the main problems in the use of diathermy was judging the effect on the choroid of applications made on full-thickness sclera. If the applications were not heavy enough the retinal seal was inadequate If the applications were too heavy, there was excessive scleral necrosis. Schepens, Black and Clark realized independently that Shapland's lamellar scleral resection could be used to thin the sclera so that the diathermy could be evenly and accurately applied to the choroid around the break. Then, when the scleral flaps were closed the sclera was nearly restored to its original strength. Schepens pioneered the use of implants (various materials buried in the bed of a lamellar scleral dissection) to reduce vitreous traction and to prevent posterior progression of the detachment. Originally, he buried polyethylene tubing over the posterior end of the most posterior break and drained the SRF. The implant was intended to act as postoperative "dyke", preventing posterior leakage of SRF from any open anterior break. He later used implants made of solid silicone to completely close all retinal breaks (Figure 8). Another of Schepens' important contributions was the introduction of the encircling procedure to permanently reduce vitreous traction.

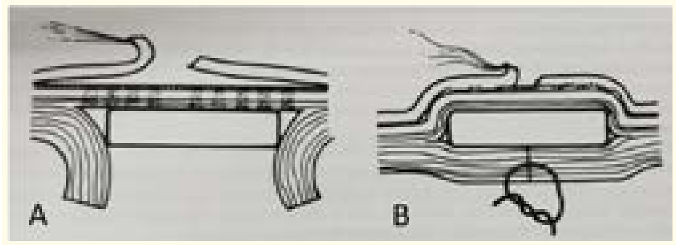

Figure 8: Schepens' operation. A: Diathermy is applied in the bed of the lamellar scleral dissection. Implant is positioned. B: Sutured scleral flaps enclose the implant. Vitreous traction is reduced.

The Machemer era (1971-Present)

Pars plana vitrectomy

The first rational attempts at vitreous surgery were made by Cibis. He realized that in eyes with PVR, preretinal and vitreous membranes prevent settling of the retina. He slowly injected liquid silicone under these membranes to strip them from the retinal surface. Although many of these eyes had complications from the silicone or subsequent redetachment of the Retina, some otherwise hopelessly lost eyes were saved.

Kasner performed the first planned open-sky vitrectomy in 1966. Shortly thereafter, Robert Machemer made a great advance in retinal surgery with the invention of the vitreous infusion suction cutter (VISC) and the development of pars plana vitrectomy. Modern pars plana vitrectomy techniques have dramatically increased the surgical success rate for retinal detachment caused by giant tear, macular holes, proliferative retinopathy, and penetrating injuries and for those complicated by PVR.

Pneumatic retinopexy (PR)

Fineberg and Norton were the first to use sulfur hexafluoride gas (SF_6) as an adjunct to scleral buckles to help close the breaks.

This relatively insoluble gas has a major advantages over air. If undiluted, it expands within the eye, so that a small injection volume results in a large bubble. Further, it is absorbed slowly, remaining for two weeks.

Kreissing and Lincoff were the first to report the use of SF_6, without drainage, curing detachments with large retinal breaks. In the mid-1980s Dominguez and Hilton independently described the use of gas to treat and cure a much large number of retinal detachment.

The procedure, called pneumocausis by Dominguez and PR by Hilton, is quite simple. The break is treated with cryotherapy and then tamponaded with gas injected into the vitreous cavity Postoperatively, the patient is positioned so that the gas bubble rise against the retinal break. The SRF is absorbed and a chorioretinal adhesion forms around the break.

Silicone oil

After Cibis, the use of silicone oil fell into disfavor for years, but its use was revived by Scott and others. Although many more complicated retinal detachment can now be repaired with advanced Vitrectomy techniques and indefinite internal tamponade with silicone oil, the visual results are not always good and such surgery in patients with a good fellow eye has been questioned.

Perfluorocarbon liquids

Even with all the refinements in vitrectomy techniques and the availability of gases and silicone oil, the repair of giant tears, especially those with rolled-over retina, was very difficult until the relatively recent introduction of the heavier-than-water perfluorocarbon liquids (PFCL). Now, retinal detachment caused by giant tears can be easily reattached in most cases. In addition, these liquids have been found to be useful in the management of other complicated retinal detachment such as those associated with trauma or PVR.

Primary vitrectomy

Pars plana Vitrectomy without SB was introduced in Europe by Kloti and in the United States by Escoffrey. Currently, the procedure consists of a pars plana vitrectomy with careful excision of the vitreous base. Subretinal fluid is removed during an air-liquid exchange through a posterior drainage retinotomy or through the original retinal break. The breaks are treated with laser photocoagulation. In addition, some surgeons place several rows or laser posterior to the entire circumference of the vitreous base.

Temporary balloon device

Lincoff and Kreissig have long been champions of non-drainage SB procedures. Their development of a balloon catheter advances this technique another degree. It is an inflatable device that is placed under Tenon's capsule and under the retinal break so that it temporarily buckles it, promoting absorption of the SRF, Further, since the balloon is removed after a week or so and since no foreign material is sutured to the eye, many complications of permanent SB are avoided.

New device and technology in vitreoretinal surgery

Vitrectomy system

- Eva (DORC, international) - Cut rate up to 16,000 cpm.
- VersaVIT 2.0 vitrectomy machine (Synergetics, Baush and Lomb, New Jersey, US).
- Cosntellation CR4 Software upgrade (Alcon, Novartis,Fort Worth, Texas)- cut rate upto 10,000.
- Stellaris PC Vision (Baush and Lomb, New Jersey, US).

Handheld tool

- 23-Gauge fragmentation needle.
- Retractable diamond dusted membrane scraper.
- DualBore SideFlo cannula.
- Steerable laser probe.
- ILM Forceps with Eckardt tip.
- Finesse flex loop (Figure 9).
- Hypersonic vitrector.

Lenses

- **Single-use sterile lenses:** Sensor medical technology have introduced sterile disposable vitrectomy lenses for use in the office and the operating theatre. The lenses include a plano lens, a magnifier lens, a biconcave lens, a 20˚ prism lens, a 30˚ prism lens, a suture ring, and a suture ring with tabs.
- **Super view disposable HTC:** The Hassan-Tornambe Disposable Contact Lens (HTC) is a single-use planoconcave contact lens with a 36˚ field of view. It incorporates an absorbent symmetrical foam ring with four supporting legs for increased stability during surgery.

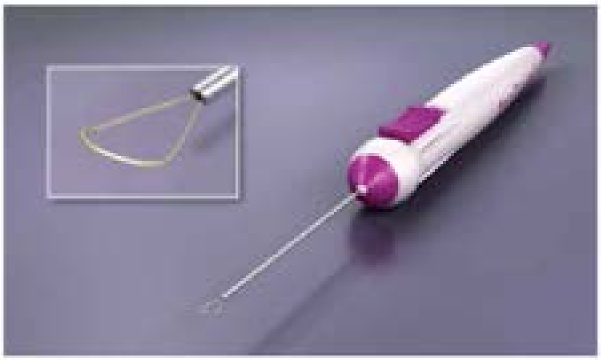

Figure 9: Finesse flex loop.

3D visualisation of vitreoretina surgery

A new concept that has garnered a great deal of attention during the past few years is 3D visualisation for vitreoretinal surgery. This is slated to provide a remarkable combination of both increased magnification and increased depth of field as compared to viewing through the optics of a microscope.

The image displayed on a 3D goggles can provide guidance to surgery through digital indicators, may overlay perioperative pictures and investigations onto the real time field and enhance the contrast and light for better visibility of epiretinal membranes etc.

Figure 10: 3D vitrectomy surgery.

Retinal robotics

Preceyes (MIOS, Lausanne, Switzerland) is the ophthalmic robotics company which was the first to perform *in vivo* tests. Four different robotic concepts are there in eye surgery. These include, the handheld tool, instrument co-manipulation, instrument telemanipulation and magnetic control. Each varies in the degree to which the robot can filter tremors, scale motion and allow automation. With telemanipulation, the intended goal is to use robotics to enhance existing procedures currently performed, and to allow surgeons to execute manoeuvres not possible with currently available technology.

The Future:...Glimpse

- In near future the first change will likely be a move from pneumatic guillotine cutters to electrically controlled cutters, allowing cut rates of 50,000 cpm and above.
- Liquefaction of vitreous will be accomplished through ultrasonic disruption or by using a femtosecond or attosecond laser to disrupt vitreous strands and allow safe and efficient vitreous removal.
- In near future we will be having two- and even one-port systems for many procedures as the functions of instruments will be combined.
- In the future switching mode during surgery will be with the help of voice command and thought-based electroencephalography commands.
- Visualization in the future may be improved with novel endoscopes and nanofiber illumination solutions.
- Intraoperative imaging will also be available as OCT technology continues to improve, and it will allow us to visualize and manipulate registered volumetric renderings in real time to more safely and effectively perform surgery (Figure 11).

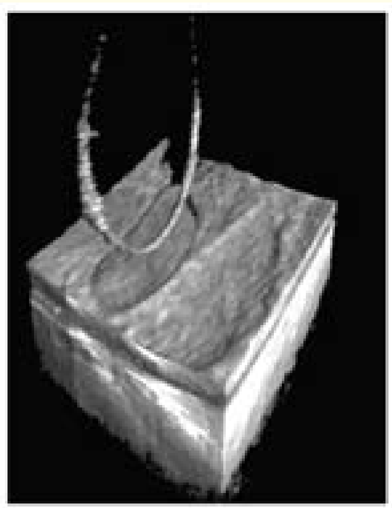

Figure 11: Real-time 3-D swept-source microscope-integrated OCT image of a nitinol loop bruising the surface of the retina during surgery.

Conclusion

In rhegmatogenous retinal detachment surgery numerous ingenious but incorrect theories and attempts of treatment was done. With advancement of instruments and innovation of new technique there is increase in success rate and lower rate of complications.

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