Taiwan Journal of Ophthalmology xxx (2016) 1–9

Contents lists available at ScienceDirect

Taiwan Journal of Ophthalmology

journal homepage: www.e-tjo.com

Review article

Primary retinal detachment: A review of the development of techniques for repair in the past 80 years☆

Ingrid Kreissig*

Department of Ophthalmology, University of Mannheim-Heidelberg, Germany

A R T I C L E I N F O

Article history:
Received 8 March 2016
Received in revised form
11 April 2016
Accepted 18 April 2016
Available online xxx

Keywords:
balloon operation
cerclage
minimal segmental buckling without drainage
pneumatic retinopexy
rules to find the break

A B S T R A C T

Background/Purpose: The evolution of present surgical techniques for reattaching a primary retinal detachment will be reviewed starting from 1929, and the present techniques analyzed in regard to their morbidity, reoperation, and long-term visual function.
Methods: Literature of retinal detachment operations during the past 80 years is reviewed, of which the author has first-hand experience during the past 40 years. There had been a change from surgery of the entire detachment to a surgery limited to the retinal break and a change from extraocular to intraocular surgery.
Results: The four major operations for repair of a primary retinal detachment in use at the beginning of the 21st century, have still one thing in common for sustained reattachment: to find and close the break that caused the primary retinal detachment and that would cause a redetachment, if not sealed completely. This is independent of whether the surgery is limited to the break or extends over the entire detachment and the same is true whether the surgery is performed as an extraocular or intraocular procedure.
Conclusion: To find and close sufficiently the break in a primary retinal detachment has accompanied the efforts of retinal detachment surgeons during the past 80 years. This is still the premise for sustained reattachment. However, today four postulates have to be fulfilled: (1) retinal reattachment with the first operation; (2) the procedure should have a minimum of morbidity; (3) the procedure should not harbor secondary complications jeopardizing regained visual acuity; and (4) the procedure should be performed on a small budget with local anesthesia.

1. Introduction

The treatment of a primary rhegmatogenous retinal detachment is again being discussed. This time the issues are no longer whether to treat the retinal break by: (1) a surgery performed without drainage or with drainage of subretinal fluid; or (2) with extraocular retinal surgery, limited to the area of the break, or extending over the entire circumference of the retina. Instead, today's question is whether to treat the retinal detachment by extraocular retinal surgery or intraocular vitreoretinal surgery for reattachment. Since this question is complex, a review will be presented of the various developments in retinal detachment surgery over the past 80 years including the present state-of-the-art surgery. After that, one will realize that it is an unending story of a leaking break in a retinal detachment that has to be found and closed once and for all.

2. Review

Prior to 1929 a retinal detachment was a blinding disorder. The first conceptual progress in the treatment of a retinal detachment was made by Gonin[1] in 1929, who postulated that a break is the cause of a retinal detachment. He applied ignipuncture around the break (Figure 1). The reattachment rate increased from practically 0% to 57%. However, precise localization of the break was very difficult. Therefore, in 1931 Guist[2] and Lindner[3] circumvented this precise localization of the break by applying many diathermy

☆ This paper was presented at the Fourth Annual Meeting of Taiwan Retinal Society, October 18, 2015 in Kaohsiung, Taiwan.

Conflicts of interest: The author has no conflicts of interest to declare.

* Corresponding author. Department of Ophthalmology, University Mannheim,-Heidelberg, Theodor-Kutzer-Ufer 1-3, 68167 Mannheim, Germany.
E-mail address: Ingrid.kreissig@medma.uni-heidelberg.de.

http://dx.doi.org/10.1016/j.tjo.2016.04.006

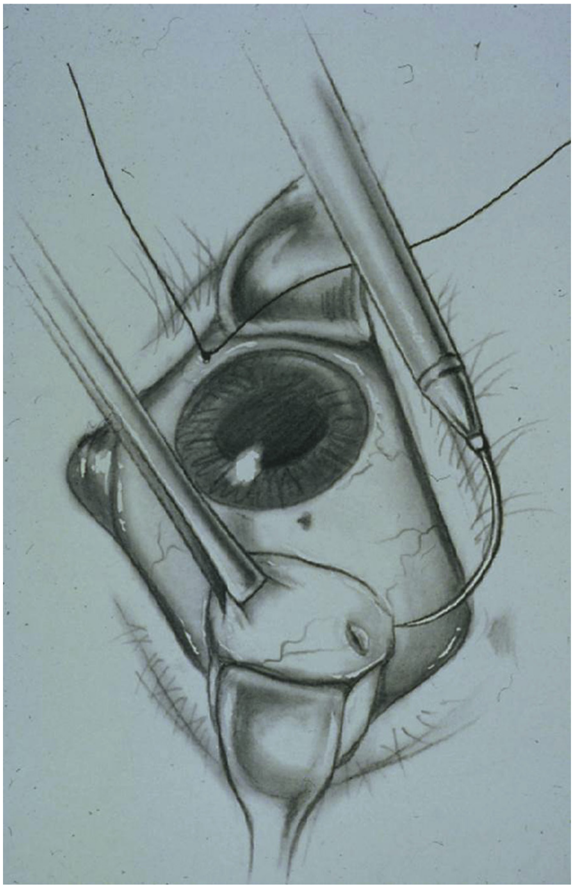

Figure 1. Gonin: Ignipuncture coagulations after drainage of subretinal fluid. Treatment is limited to the area of the break. *Note*. From Michels R, Wilkinson C, Rice T, 1990, *Retinal Detachment*, *5*, p. 258, St Louis: C.V. Mosby. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

coagulations as a kind of barricade posterior to the break to prevent a redetachment. Larsson[4] extended the treatment further by applying full-thickness diathermy in the quadrant surrounding the retinal break (Figure 2). Retinal reattachment increased to 70%, but redetachment occurred again, because the retinal break was not sealed sufficiently.

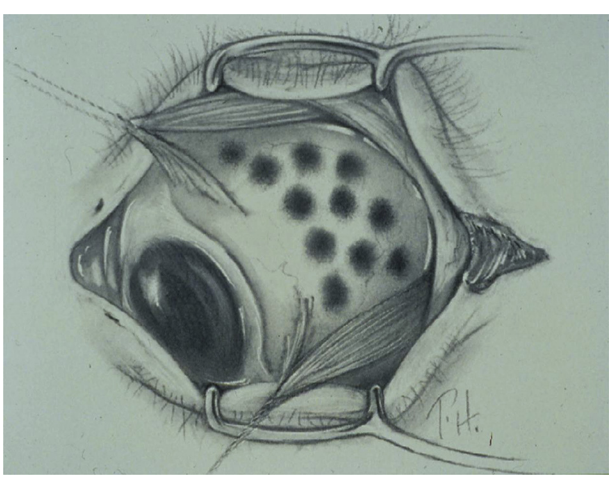

Figure 2. Larsson: Coagulations are placed over entire quadrant of the break to protect against future leakage. *Note*. From Michels R, Wilkinson C, Rice T, 1990, *Retinal Detachment*, *5*, p. 260, St Louis: C.V. Mosby. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

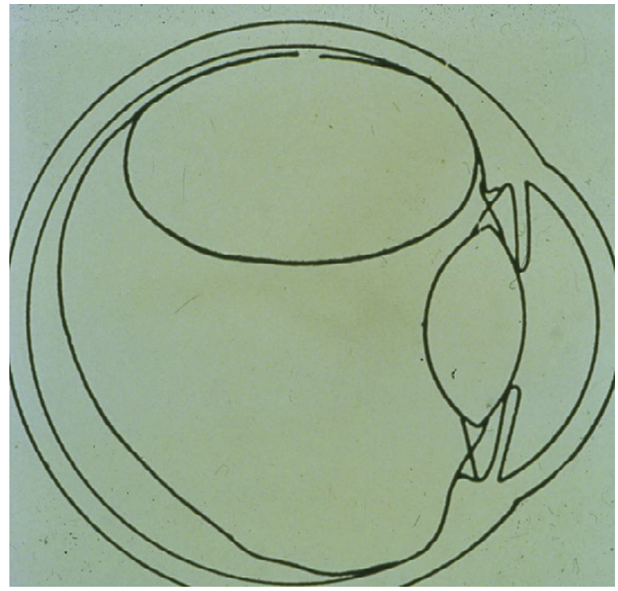

Figure 3. Rosengren: Use of an intraocular air bubble to tamponade *ab interno* the break of the retinal detachment. *Note*. From Kreissig I. 2000, *A Practical Guide to Minimal Surgery for Retinal Detachment: Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations*, *10*, p. 110, Stuttgart: Thieme. Copyright XXXX, *Name of Copyright Holder*. Reprinted with permission.

Further conceptual progress in the treatment of a retinal detachment evolved with Rosengren[5] in 1938. He again limited the coagulations to the area of the break, but added, after drainage of the subretinal fluid, an intraocular air bubble to tamponade the break *ab interno* (Figure 3). Retinal reattachment increased to 77%.

Again, however, redetachment occurred, because the air had left the eye too early, before a sufficiently strong adhesion around the break had developed and, therefore, the break again started to leak. Another problem was—as experienced earlier—the precise localization of the break and the limiting of the coagulations to the area around the break.

Therefore, again surgery with extensive coagulations was applied to provide a barricade posterior to the break. This time, however, a scleral resection was added in the area of the coagulations (Figure 4). Subsequently, a plomb was embedded into the resection, thus creating a high wall (Figure 5A–D). In addition,

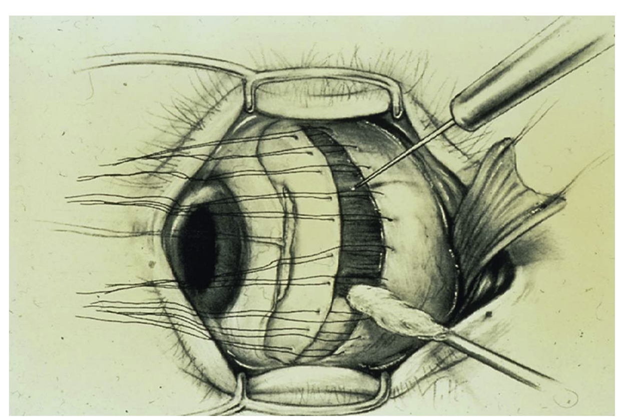

Figure 4. Scleral resection with coagulations, located posteriorly to the break, to create by the resulting indentation *ab externo* a better barrier against future leakage and redetachment. *Note*. From Michels R, Wilkinson C, Rice T, 1990, *Retinal Detachment*, *5*, p. 275, St Louis: C.V. Mosby. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

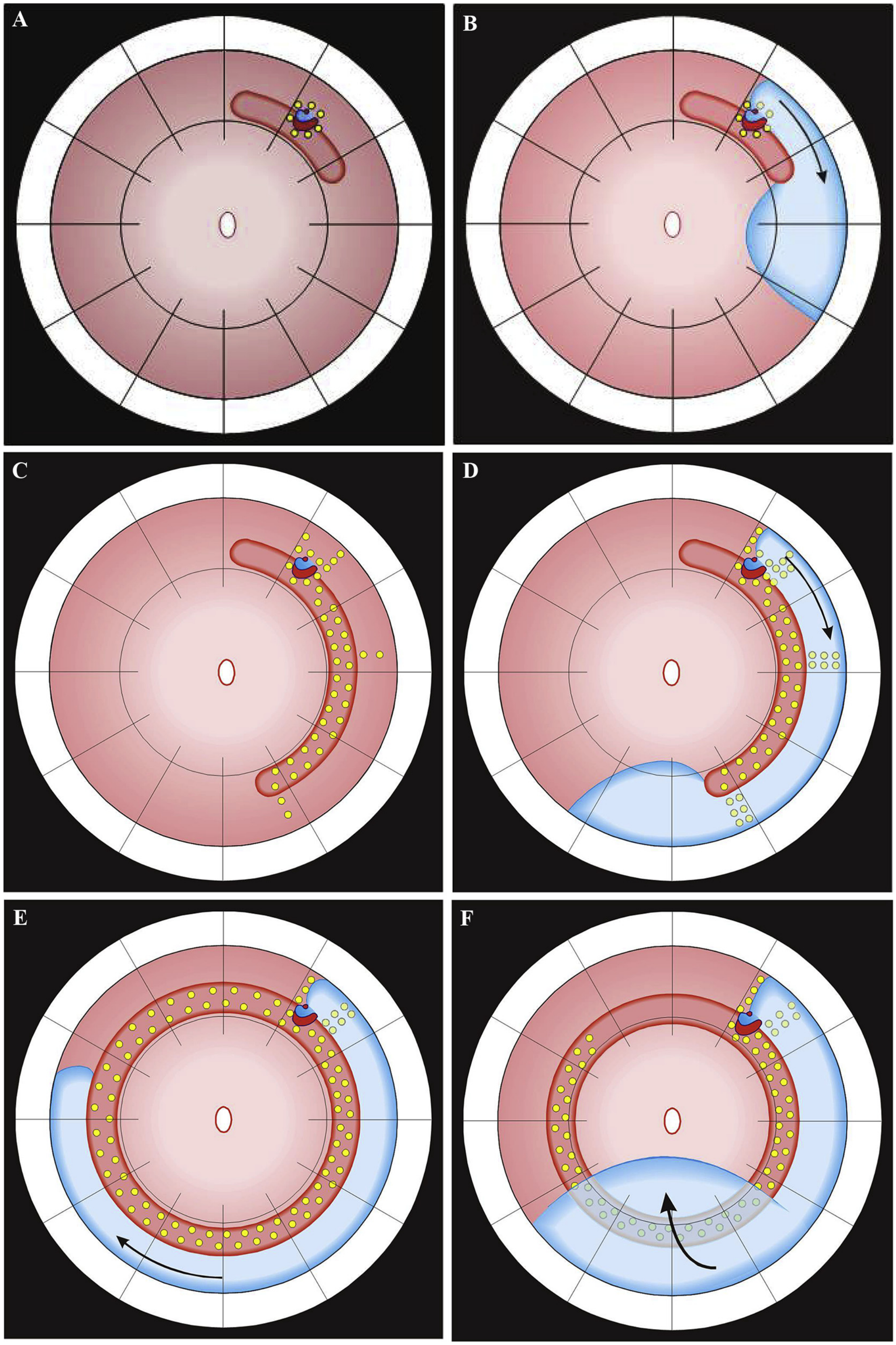

Figure 5. (A) A segmental plomb, embedded into the scleral resection, with the retinal break positioned on the anterior edge of the buckle and with diathermy coagulations around the break. (B) Retinal break starts to leak anteriorly since not supported sufficiently by the buckle, resulting in a redetachment anterior to the buckle, descending inferiorly and starting to redetach the posterior retina. (C) Larger segmental plomb with the retinal break, being again positioned on the anterior edge of the buckle, surrounded with diathermy coagulations, additional coagulations on the entire buckle and several so-called coagulation barriers towards the ora serrata. (D) Retinal break again starts to leak anteriorly, resulting in a redetachment anterior to the buckle, which subsequently crosses the various barriers of coagulations and finally progresses towards the posterior retina, resulting in redetachment. (E) Circular buckle (so-called cerclage) with coagulations spread over the entire buckle and anterior to it with a starting redetachment descending anteriorly of the buckle. Due to the very anterior position of the cerclage, the momentum of subretinal fluid seemed not yet large enough to cross the cerclage and to redetach the posterior retina. (F) A more posteriorly positioned cerclage with coagulations on the buckle and anterior to it. This time the anterior redetachment, originating from the leaking break, crosses again the barriers of coagulations, but due to the larger momentum of subretinal fluid, it crosses the cerclage inferiorly and progresses towards the posterior retina. *Note*. From Kreissig I, 2005, *Primary Retinal Detachment: Options for Repair*, *9*, p. 179,180. Berlin: Springer. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

to prevent future leakage of the break, several lines of coagulations were placed from the buckle towards the *ora serrata*. However, since the break was not tamponaded anteriorly, the break again started to leak, the detachment crossed the barricades of coagulations, descended behind the buckle, inferiorly crossed it, and redetached the posterior retina.

The logical consequence might have been to search for a more sufficient tamponade of the leaking break, but, instead, a more effective barrier of the redetachment was created. Thus, in 1953 the former segmental buckle barrier was enlarged to a circular plomb by Schepens[6] and in 1958 by Arruga,[7] and the cerclage operation with drainage of subretinal fluid evolved (Figures 5E and 5F). This circular buckle operation represented a maximum of a barrier for the leaking break. Extensive coagulations were placed on the circular buckle to secure the anterior retina. More retinas were reattached now, i.e., > 80%, but redetachment occurred again due to the still leaking break. At reoperation, the cerclage was either made higher by more constriction of the globe, or positioned more posteriorly. Despite all this, if the break was not tamponaded sufficiently, it again started to leak and redetachment occurred. The developing anterior redetachment crossed the barriers of coagulations, subsequently as well the cerclage and finally redetached the posterior retina.

In subsequent years, the cerclage technique with drainage of subretinal fluid was further refined by Schepens[6] and Pruett.[8] Now the leaking breaks were placed on the circular buckle and, if needed, tamponaded by an additional plomb or wedge. However, the drainage of this technique represented a dangerous and vision-threatening complication: there was intraocular hemorrhage in 7–16% of cases. Additional complications consisted of choroidals in 8.6% and intraocular infection and incarceration of vitreous and retina.[9–12] Lincoff et al[13] recently found that an encircling band also reduces the ocular blood flow, resulting in a relative ischemia in the anterior and posterior segment of the eye with a possible deleterious effect on visual function. Therefore, a cerclage should be cut after retinal stability has been achieved, at least after 6 months.

The cerclage operation with drainage of subretinal fluid represents the first procedure still in use today. With the cerclage operation, over 80% of retinas are reattached.

The third conceptual progress in the repair of a retinal detachment was made by Custodis[14] in 1953. His surgery again was limited to the area of the break and consisted of full-thickness diathermy and an elastic polyviol plomb fixated on the sclera, but—for the first time—the detachment surgery was done without drainage of subretinal fluid. This was made feasible by using an elastic plomb. However, unexpected serious postoperative complications developed, which were caused by the somehow toxic polyviol plomb in combination with full-thickness diathermy of the sclera. There were reports of a scleral abscess, endophthalmitis, and even an enucleation, and this caused the end of the Custodis[14] procedure in Europe as well as in America.[15]

This was not the case for everybody in America, at least not for Harvey Lincoff. He, with an open mind for new developments, was convinced of the rational approach of this technique. Therefore, he searched for a means to avoid the postoperative disastrous complications. In 1965 he replaced the elastic polyviol plomb by the tissue-inert elastic sponge and the necrotizing diathermy by cryosurgery.[16–19] However, cryopexy was not at all accepted, because there were great doubts about its adhesive strength. Therefore, from 1969 to 1972, when Kreissig was working with Lincoff in New York, the open question about the adhesive strength of the cryosurgical adhesion was addressed by experiments on 336 rabbit eyes. It could be confirmed that: (1) the cryosurgical adhesion is sufficiently strong after 7 days; (2) the cryosurgical adhesion reaches its maximum at 12 days; and (3) it is possible to produce with cryosurgery adhesions of different strengths: when a cryo lesion is applied under ophthalmological control, after a light cryo application a light adhesion results; after a medium lesion, a medium adhesion; and after a heavy lesion, a strong adhesion.

When Kreissig returned from New York to the Department of Ophthalmology in Bonn, Germany in 1972, she started to treat retinal detachments with this new technique, consisting of transscleral cryopexy with ophthalmoscopic control of every lesion around the break and a sponge buckle limited to the area of the break and this without drainage of subretinal fluid. After operating with this new localized atraumatic surgery on retinal detachments for 5 years, Kreissig[20] reported the favorable results in 1978. Subsequently this was followed by her numerous teaching courses on this so-called minimal surgery without drainage in various countries and up to the end of 2015 there have been 114 such courses. However, soon it was realized that the spontaneous reattachment without drainage of subretinal fluid only occurred postoperatively if all of the breaks were found, and buckled sufficiently. Therefore, detecting all of the breaks had become the main goal of diagnostics prior to this minimal surgery.

The fourth conceptual progress in repair of a retinal detachment came about by a rational approach to find the causative break of a retinal detachment by Lincoff et al.[21–24] These rules had become essential for a successful repair of a primary retinal detachment and for a detachment up for reoperation. There are four rules on how to find the primary break (Figure 6) and four rules on how to find the missed break in a detachment up for reoperation (Figure 7). In

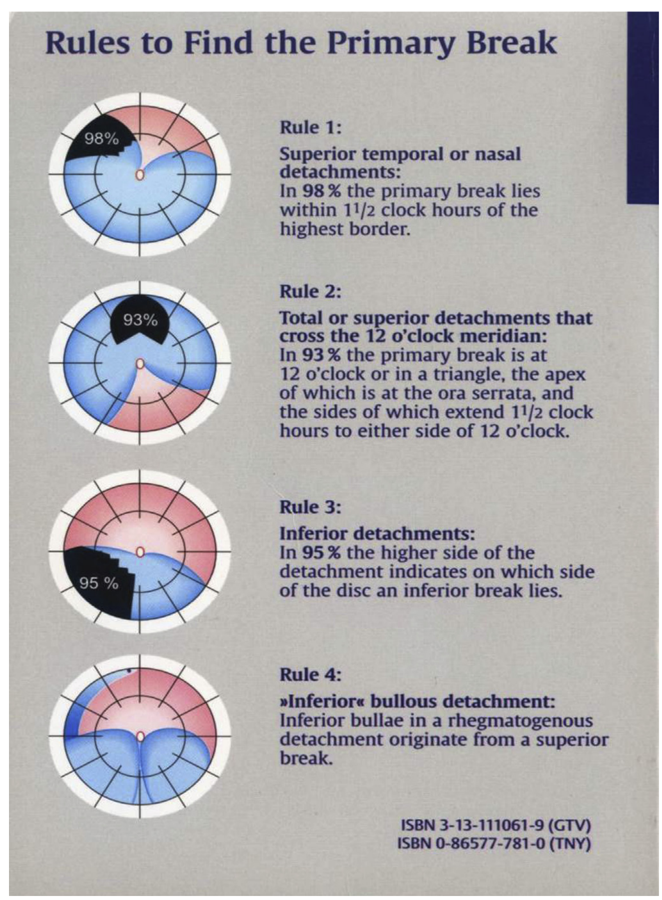

Figure 6. The four rules to find the primary break in a retinal detachment. *Note*. From Kreissig I, 2000, *A Practical Guide to Minimal Surgery for Retinal Detachment: Diagnostics, Segmental Buckling without Drainage, Case Presentations*. Stuttgart: Thieme Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

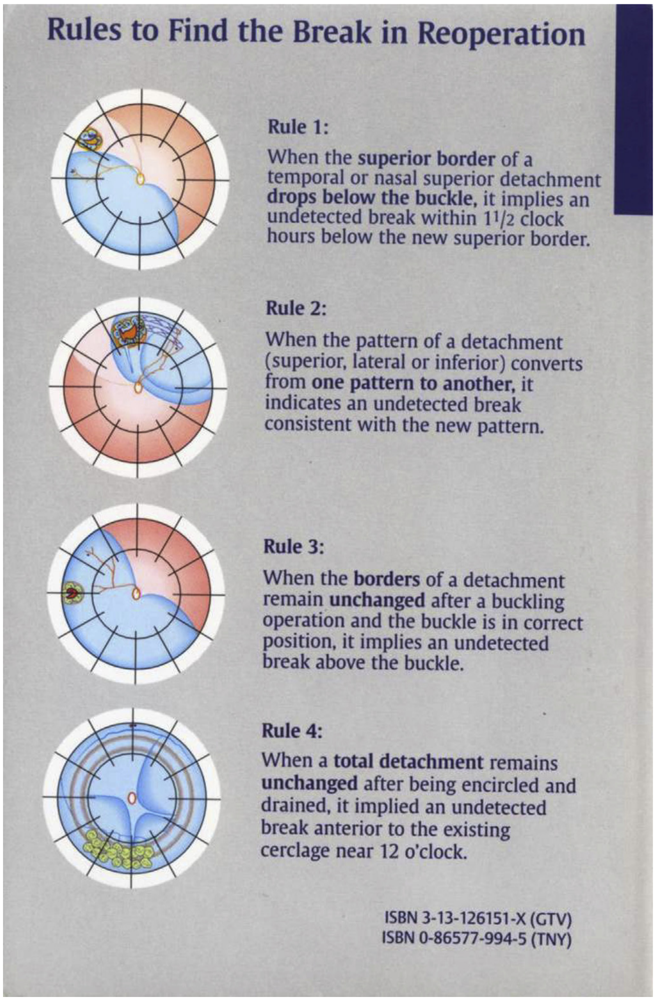

Figure 7. The four rules to find the missed break in a retinal detachment up for reoperation. *Note*. From Kreissig I, 2000, *A Practical Guide to Minimal Surgery for Retinal Detachment: Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations*. Stuttgart: Thieme. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

addition, it was found that a break is better tamponaded by a radial buckle than a circumferential buckle, because posterior fish-mouthing and anterior leakage of the break can be circumvented (Figure 8).[25]

All of these achievements resulted in a further refinement of the cryosurgical detachment operation without drainage, which was now called minimal segmental buckling without drainage of subretinal fluid.

3. Minimal segmental buckling without drainage or minimal surgery

This represents the second procedure in use today for repair of a primary retinal detachment (Figure 9). It consists of cryopexy and a sponge in the area of the break without drainage of subretinal fluid. Retinal reattachment resulted after one operation in 93% and after one reoperation in 97%. After this minimal surgery, proliferative vitreoretinopathy (PVR), as cause of final failure, was reduced to 1.9%.[26,27] Regained visual acuity was not jeopardized by secondary complications. During a follow-up of 15 years it decreased by 0.07 lines in the Snellen chart per year, but this decrease was not statistically different from the one occurring in the unoperated fellow eye over this time (Figure 10). Therefore, the segmental buckle in place did not jeopardize postoperative visual acuity in comparison to the fellow eye.

To reduce the surgical trauma for repair of a retinal detachment further, in 1979 the elastic sponge buckle was replaced by a temporary elastic balloon plomb with no intrascleral sutures for fixation and as well without drainage of subretinal fluid.[27]

The fifth conceptual progress in repair of a retinal detachment came about with the development of this temporary balloon buckle being unsecured by intrascleral sutures.

4. The Lincoff–Kreissig balloon

This new procedure is the balloon buckle operation, using a Lincoff–Kreissig balloon (Figure 11)[28], in which: (1) the buckle is not fixated by a suture and (2) the balloon buckle is removed after 1 week. At that point it proved to be of help, the results of our

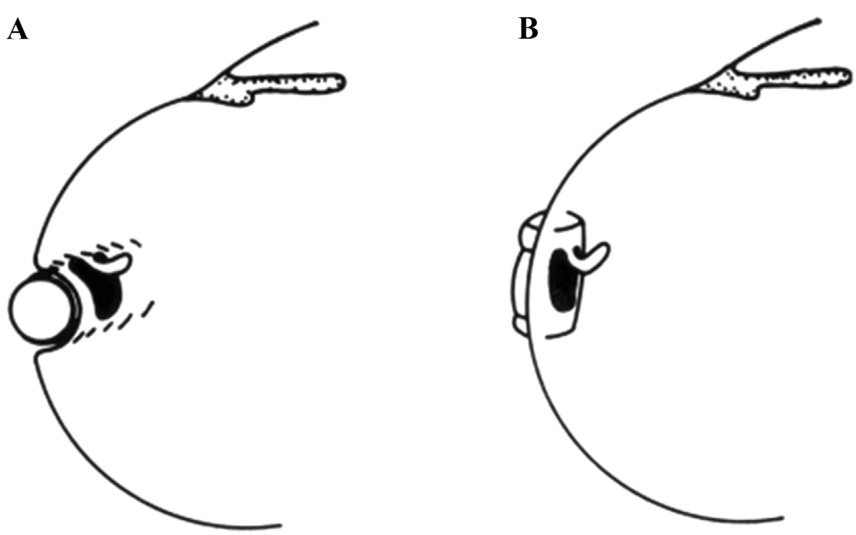

Figure 8. Optimal orientation of a segmental buckle for tamponading a horseshoe tear. Using a circumferential buckle (A), the horseshoe tear is not tamponaded adequately. The operculum, an area of future traction, is not on the ridge of the buckle, but on the descending slope. In addition, there is a risk of a posterior radial fold, so-called *fishmouthing*, with subsequent leakage of the tear. Using a short radial buckle (B) provides an optimal tamponade for the horseshoe tear. The entire tear is placed on the ridge of the buckle, i.e., this counteracts posterior *fishmouthing* of the tear and provides an optimal support for the operculum, counteracting at the same time future anterior vitreous traction. *Note*. From Kreissig I, 2000, *A Practical Guide to Minimal Surgery for Retinal detachment. Diagnostics, Segmental Buckling without Drainage, Case Presentations*, *8*, p. 141. Stuttgart: Thieme. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

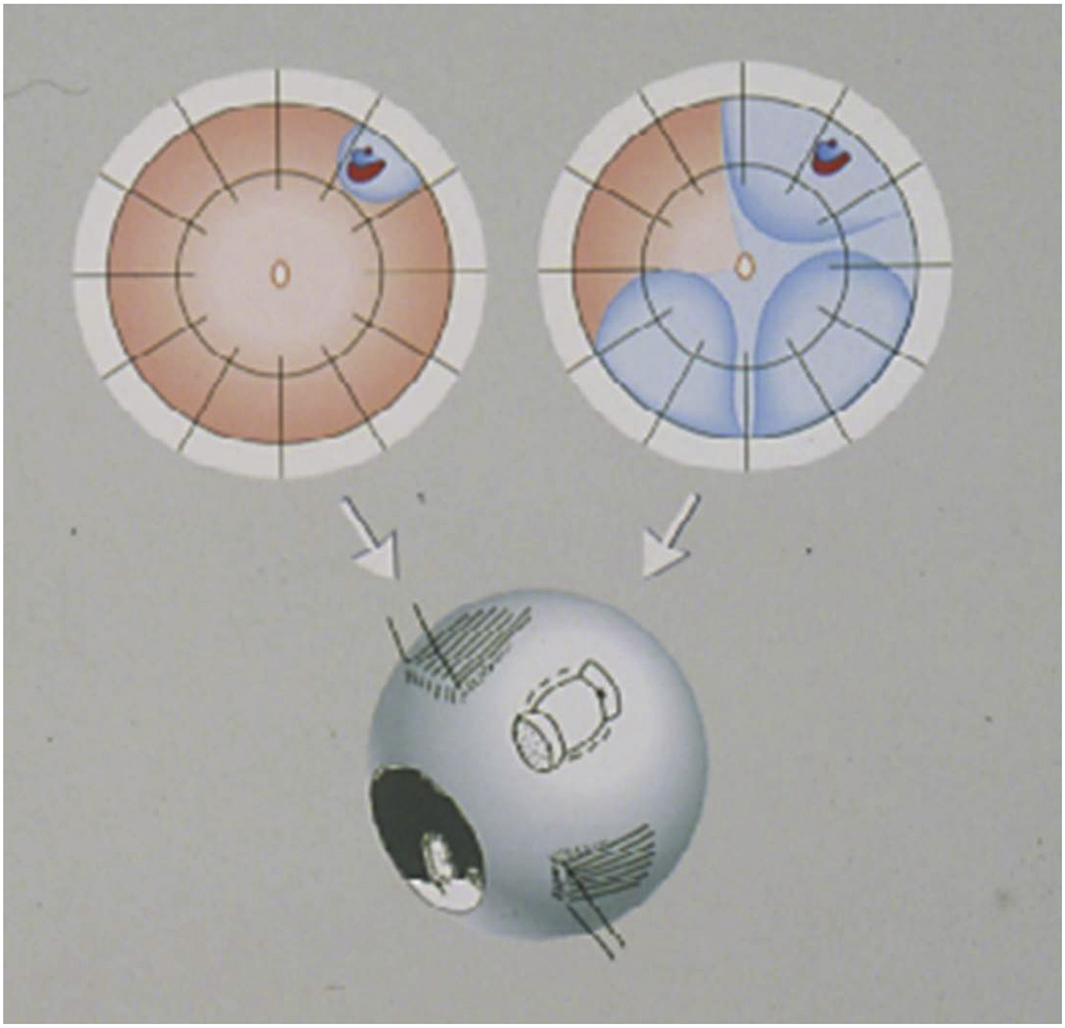

Figure 9. Minimal segmental buckling without drainage, so-called extraocular minimal surgery: The treatment is limited to the area of the break and not determined by the extent of the detachment. The small (top left) and the more extensive detachment (top right) are caused by the same horseshoe tear at 1:00. The treatment of both detachments is the same, consisting of buckling the tear either by a segmental sponge (as depicted) or a temporary balloon without drainage of subretinal fluid. *Note*. From Kreissig I, 2000, *A Practical Guide to Minimal Surgery for Retinal Detachment: Diagnostics, Segmental Buckling without Drainage, Case Presentations*. Stuttgart: Thieme. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

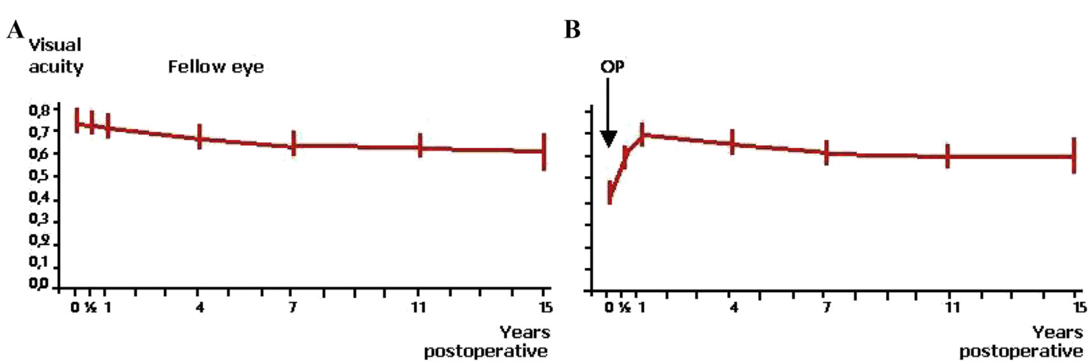

Figure 10. Course of mean visual acuity of fellow and operated eyes during 15-year follow-up. Course of mean visual acuity in the 107 unoperated fellow eyes during the 15-year follow-up (A). Course of mean visual acuity in the 107 eyes with retinal detachments operated with extraocular minimal surgery, consisting of segmental sponge buckle(s) without drainage during 15 years after surgery (B). Preoperative visual acuity of 0.3 had increased to 0.5 at 6 months and to 0.6 at 1 year, and decreased to 0.5 after 15 years. Seventy-two patients were alive 15 years after surgery. During the study period of 15 years, the difference in decrease of visual acuity was not statistically significant between the unoperated fellow eyes and operated eyes with the segmental buckle(s) in place at any interval.

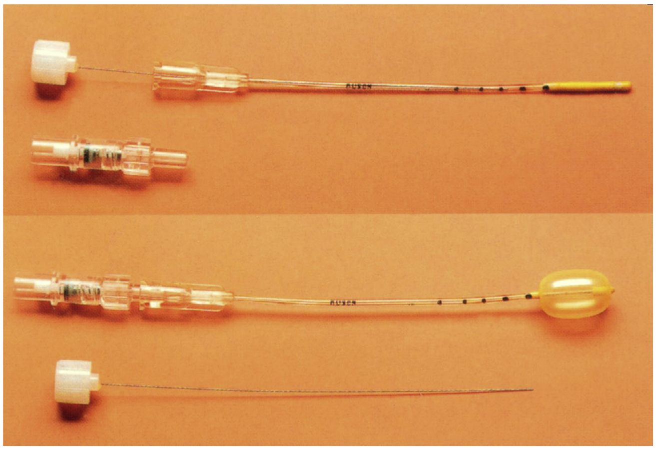

Figure 11. Lincoff–Kreissig balloon: The balloon has (1) a metal stylette to facilitate insertion into the parabulbar space and (2) calibrations (black marks) on the tube to enable a more precise determination of the balloon's position in the parabulbar space. Deflated balloon catheter with stylette in place; beneath it the adapter (top). Inflated balloon (0.75 ml of sterile water) with self-sealing valve in place; beneath it the withdrawn stylette (bottom). *Note.* From Kreissig I, 2000. *A Practical Guide to Minimal Surgery for Retinal Detachment: Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations, 9*, p. 5. Stuttgart: Thieme. Copyright 19XX, Name of Copyright Holder. Reprinted with permission.

earlier animal experiments on the strength of the cryosurgical adhesion and on the time it takes to develop a strong enough adhesion ranging at 7 days. The balloon operation can be applied for detachments with one break or a group of breaks within 1 hour.

The results after one balloon operation were reattachment in 93%. After balloon removal, redetachment occurred postoperatively within 6 months in 2% of cases, but after reoperation, reattachment resulted in 99% during a follow-up of 34 months. As expected, after this very atraumatic procedure, postoperative PVR was further reduced to 0.2%.[29,30]

Parallel to these refinements in segmental buckling without drainage, it was found, that giant tears were not suitable for buckling. The long circumferential buckles caused constriction of the globe with leaking radial folds resulting in posterior redetachment. Therefore, in 1973 Norton[31] and Lincoff[32] instead introduced an intraocular gas bubble as tamponade for these giant tears. After drainage of subretinal fluid, the gas SF_6 was injected into the vitreous and the edges of the tear sealed off with cryopexy or with laser coagulation after reattachment. However, with this gas operation the great achievement of nondrainage again was given up, because prior to the gas injection, drainage of subretinal fluid was required to obtain the volume needed for an intraocular injection.

Therefore, in 1974, Kreissig began to look for a possibility to sustain nondrainage as well for this gas operation. After a preceding ocular compression, it became possible to inject 0.4 mL of SF6 without prior drainage. Since the gas was expandable, its volume subsequently increased twice. Thus—for the first time—nondrainage was also transferred to the gas operation, published in 1979.[33]

The sixth conceptual change in repair of a retinal detachment came about with the expanding-gas operation without drainage.

5. Expanding-gas operation

This was applied to difficult detachments, i.e., detachments with giant tears and posterior breaks. However, the postoperative PVR was high. Therefore, this nondrainage expanding-gas operation was reserved for detachments with complicated breaks not suitable for buckling.[34,35] However, it was not used for detachments with uncomplicated breaks, because: (1) the rate of postoperative PVR was too high; and (2) at that time the balloon operation was already available, which had practically no postoperative PVR, i.e., ranging at 0.2% in comparison.

The gas operation with SF6 for complicated tears was further improved with the introduction of the perfluorocarbon gases by Lincoff and his group. The rate of expansion of the various perfluorocarbon gases was: 2× for CF_4, 3.3× for C_2F_6, 4× for C_3F_8, and 6× for C_4F_{10} of their original volume (Figure 12).[36] However, a gas with a larger expansion has a longer intraocular duration which resulted in a higher rate of PVR. Thus, the half-life (representing the therapeutic volume of an intraocular gas) of these gases ranges at: 6 days for CF_4, 10 days for C_2F_6, 35 days for C_3F_8, and at 45 days for C_4F_{10} (Figure 13).[37] Such a long half-life of an intraocular gas is not necessary, because it will take only 7 days to develop a sufficiently strong retinal adhesion, as was determined by our previous animal experiments.[16,17] Therefore, a long intraocular duration of gas unnecessarily increases the rate of PVR.

Despite the risk of a higher rate of PVR after intraocular gas, the original expanding-gas operation without drainage of 1979 was re-introduced by Hilton and Grizzard[38] and Dominguez et al[39] in 1986. This time, however, this gas operation without drainage was called pneumatic retinopexy and applied to uncomplicated detachments.

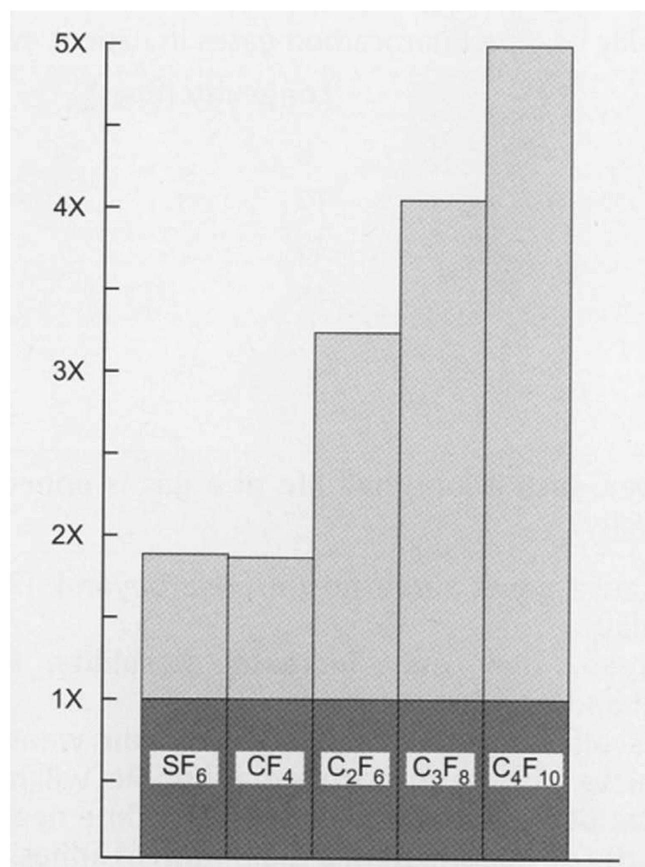

Figure 12. Expansion of four straight-chain perfluorocarbon gases and SF_6 in patient eyes. SF_6 and CF_4 have an expansion coefficient of 1.9×, C_2F_6 of 3.3×, C_3F_8 of 4×, and C_4F_{10} of 5×. *Note.* From Kreissig I, 2000, *A Practical Guide to Minimal Surgery for Retinal Detachment: Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations, 10*, p. 130, Stuttgart: Thieme. Copyright 19XX, *Name of Copyright Holder*. Reprinted with permission.

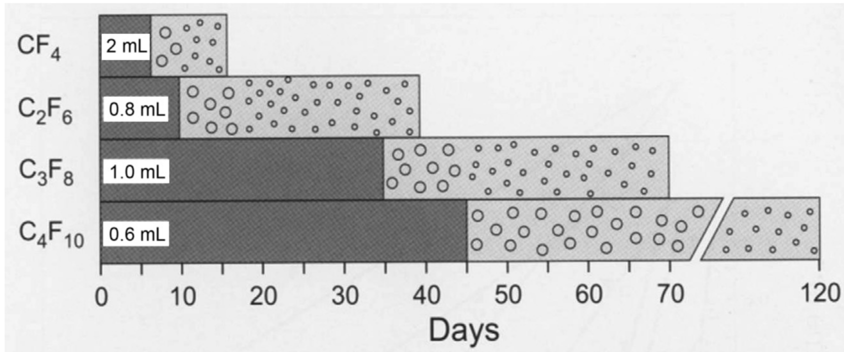

Figure 13. Disappearance time of four straight-chain perfluorocarbon gases in patient eyes. The left portion of each bar (darker gray) indicates the time taken for the expanded volume of gas to diminish to half volume. Half-life of CF_4 was 6 days, of C_2F_6 10 days, of C_3F_8 24–35 days, and of C_4F_{10} at 45 days. *Note.* From Kreissig I, 2000, *A Practical Guide to Minimal Surgery for Retinal Detachment: Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations*, *10*, p. 125, Stuttgart: Thieme. Copyright 19XX, Name of Copyright Holder. Reprinted with permission.

6. Pneumatic retinopexy

This is the third surgery in use today for repair of a primary retinal detachment. The primary reattachment rate after pneumatic retinopexy of uncomplicated detachments is 91%, but after disappearance of the gas, reattachment is reduced to 80%. After several reoperations reattachment is increased to 99%, but as a serious complication after the intraocular gas there will be: (1) new breaks in 15%; and (2) postoperative PVR in 4%.[28] Soon another concept evolved to decrease the high rate of postoperative PVR after the intraocular gas.

The seventh conceptual change in repair of a retinal detachment was already conceived in 1972 by Machemer et al[40], when he introduced vitrectomy. At that time, however, he developed vitrectomy for difficult retinal detachments complicated by vitreous traction and vitreoretinal proliferation. The first vitrectomy instrument, the VISC, was somewhat bulky, but it was optimally refined in the subsequent years.

In 1985, it was suddenly concluded that perhaps an additional vitrectomy, performed prior to pneumatic retinopexy, might reduce the postoperative high rate of postoperative PVR and the development of new breaks. This procedure was called primary vitrectomy and used for uncomplicated detachments.

7. Primary vitrectomy

This is the fourth operation in use for repair of a primary retinal detachment. The primary vitrectomy was used to eliminate postoperative PVR and the development of new breaks. However, this was not achieved. In the beginning, postoperative PVR after primary vitrectomy was about 11.5% and by a more recent meta-analysis—after more experience with this procedure and the use of more refined instruments—it could be reduced, but was still 5.3%. In addition, the rate of reoperations, primarily about 24.5%, was reduced to 13.3%, as determined by a more recent metaanalysis.[41] A certain drawback that primary vitrectomy still harbors is that in a phakic eye a subsequent cataract will develop. In a subsequent risk ratio analysis of 3384 intraocular procedures versus 1854 extraocular procedures, Lincoff et al[41]could verify that the rate of reoperations after intraocular surgery is 2.5× higher than after extraocular surgery and the rate of postoperative PVR even 6× higher after intraocular surgery than after extraocular segmental buckling.

8. Discussion

In 2015 we have two extraocular and two intraocular techniques available for repair of a primary rhegmatogenous retinal detachment. To succeed with any of these methods, the leaking break has to be: (1) found and (2) sealed off sufficiently.

In a recently published multicenter study in Europe comparing the results after primary vitrectomy for medium difficult retinal detachments with those after scleral buckling, the results were as follows: in phakic eyes, the functional results after scleral buckling were better than after primary vitrectomy; and, in pseudophakic eyes, the results after primary vitrectomy only were better if a cerclage was added. After several reoperations, however, the results for both procedures were comparable.[42,43]

Therefore, if there is a retinal detachment in a phakic eye, the prognosis after buckling is better, implying better visual function than after primary vitrectomy. However, to succeed with any of these methods, the break has to be found and sealed off sufficiently. In each method this is achieved differently and the emphasis on the retinal break varies significantly. The question remains: which procedure is better? On one side we have an exclusive treatment of the leaking break by an extraocular approach without drainage and segmental buckling either by a temporary balloon or a sponge buckle sewed onto sclera, representing the so-called extraocular minimal surgery. It would not be correct not to mention that many of the present extraocular detachment surgeons are still using a cerclage with extensive coagulations to seal off the leaking break(s) and suspicious areas in the periphery with the addition of drainage of subretinal fluid. Actually, they have not accepted the Custodis principle because their surgery is not limited to the area of the leaking break(s) and drainage of subretinal fluid is added.

On the other side, we have the treatment of the leaking break in a primary retinal detachment by an intraocular procedure, either by pneumatic retinopexy with coagulations limited to the area of the break, as suggested by Hilton and Grizzard[38] in 1986, or as modified by Tornambe[44] with coagulations spread over the entire retinal periphery by creating a circular barrier of coagulations (a kind of a cerclage of coagulations) against a leaking break, or by vitrectomy with a gas injection, combined with coagulations, which might be placed over the entire retinal periphery, or even with an additional cerclage. According to the reports of the various authors, with every surgical procedure and after reoperations, retinal reattachment can be obtained in 94–99% of cases.

The difference lies in the morbidity of each procedure, i.e., in the rate of postoperative PVR, new breaks, reoperations, and secondary complications, which may jeopardize long-term visual function and require additional surgery in the anterior or posterior segment of the eye to sustain vision.

With each of the four presented procedures for repair of a primary retinal detachment, the following issues should be fulfilled: (1) to achieve retinal reattachment with only one operation; (2) to

Please cite this article in press as: Kreissig I, Primary retinal detachment: A review of the development of techniques for repair in the past 80 years, Taiwan Journal of Ophthalmology (2016), http://dx.doi.org/10.1016/j.tjo.2016.04.006

achieve retinal reattachment by a procedure with a minimum of morbidity; (3) to perform the surgery on a small budget and under local anesthesia; and (4) not to induce secondary complications jeopardizing regained visual function during long-term follow-up.

Therefore, when considering these four issues, it might even be possible that the pendulum of retinal detachment surgery, as just witnessed during the past 80 years, might again swing back to an extraocular surgery, in this case perhaps towards minimal segmental buckling, limited to the area of the break without drainage and with a minimum of morbidity.[26–28] At the other end of the spectrum, there might be a more refined vitrectomy with new intraocular tamponades and more sophisticated vitrectomy instruments, resulting in a further minimized vitrectomy with fewer complications.[45,46]

Therefore, let us be open to any new upcoming developments in retinal and vitreous surgery, but at the same time always keep a critical eye on the accompanying morbidity and long-term complications that might jeopardize regained visual function.

References

1. Gonin J. Le traitement opératoire du décollement rétinien. Conférence aux journées médicales de Bruxelles. *Bruxelles-Méd*. 1930;23. No 17.
2. Guist E. Eine neue Ablatiooperation. *Ztsch Augenheilk*. 1931;74:232–242.
3. Lindner K. Ein Beitrag zur Entstehung und Behandlung der idiopathischen und der traumatischen Netzhautablösung. *Graefes Arch Ophthalmol*. 1931;127:177–295.
4. Larsson S. Electro-diathermy in detachment of the retina. *Arch Ophthalmol*. 1932;7:661–665.
5. Rosengren B. Über die Behandlung der Netzhautablösung mittelst Diathermie und Luftinjektion in den Glaskörper. *Acta Ophthalmol*. 1938;16:3–42.
6. Schepens CL. Prognosis and treatment of retinal detachment. The Mark J Schoenberg Memorial Lecture. A review by Kronenberg B, New York Society for Clinical Ophthalmology. *Am J Ophthalmol*. 1953;36:1739–1756.
7. Arruga MH. Le cerclage equatorial pour traiter le decollement retinien. *Bull Soc Franc Ophtal*. 1958;71:571–580.
8. Pruett RC. The fishmouth phenomenon. II. Wedge scleral buckling. *Arch Ophthalmol*. 1977;95:1782–1787.
9. Kreissig I. Kryopexie in der Ablatio-Chirurgie (2. Mitteilung). *Klin Mbl Augenheilk*. 1971;159:737–741.
10. Blagojević M, Ilić R. Drainage of the subretinal fluid and injection of saline solution in the vitreous body. *Mod Probl Ophthal*. 1975;15:169–173.
11. Hübner H, Böke W. Klinische und technische Aspekte der subretinalen Drainage. *Mod Probl Ophthal*. 1975;15:137–142.
12. Törnquist R, Törnquist P. Retinal detachment. III Surgical results. *Acta Ophthalmol*. 1988;66:630–636.
13. Lincoff H, Stopa M, Kreissig I, et al. Cutting the encircling band. *Retina*. 2006;26:650–654.
14. Custodis E. Bedeutet die Plombenaufnähung auf die Sklera einen Fortschritt in der operativen Behandlung der Netzhautablösung? *Berichte der Deutschen Ophthalmologischen Gesellschaft*. 1953;58:102–105.
15. Schepens CL, Okamura ID, Brockhurst RJ, Regan CD. Sceral buckling procedures. V. sutures and silicone implants. *Arch Ophthalmol*. 1960;64:868–881.
16. Lincoff H, O'Connor P, Kreissig I. Die Retina-Adhäsion nach Kryopexie. *Klin Monatsbl Augenheilkd*. 1970;156:771–783.
17. Kreissig I, Lincoff H. Ultrastruktur der Kryopexieadhäsion. In: *DOG Symposium Die Prophylaxe der idiopathischen Netzhautabhebung*. München: Bergmann; 1971:191–205.
18. Lincoff H, Baras I, McLean J. Modifications to the Custodis procedure for retinal detachment. *Arch Ophthalmol*. 1965;73:160–163.
19. Kreissig I, Lincoff H. Mechanism of retinal attachment after cryosurgery. *Trans Ophthalmol Soc UK*. 1975;95:148–157.
20. Kreissig I. Detachment surgery without drainage. *Klin Mbl Augenheilk*. 1978;173:140–149.
21. Lincoff H, Gieser R. Finding the retinal hole. *Arch Ophthalmol*. 1971;85:565–569.
22. Kreissig I. *A Practical Guide to Minimal Surgery for Retinal Detachment: Vol. 1. Diagnostics, Segmental Buckling without Drainage, Case Presentations*2. Stuttgart: Thieme; 2000:14–15.
23. Lincoff H, Kreissig I. Extraocular repeat surgery of retinal detachment. A minimal approach. *Ophthalmology*. 1996;103:1586–1592.
24. Kreissig I. *A Practical Guide to Minimal Surgery for Retinal Detachment: Vol. 2. Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations*14. Stuttgart: Thieme; 2000:320–321.
25. Lincoff H, Kreissig I. Advantages of radial buckling. *Am J Ophthalmol*. 1975;79:955–957.
26. Kreissig I, Rose D, Jost B. Minimized surgery for retinal detachments with segmental buckling and nondrainage. An 11-year follow-up. *Retina*. 1992;12:224–231.
27. Kreissig I, Simader E, Fahle M, Lincoff H. Visual acuity after segmental buckling and non-drainage: a 15-year follow-up. *Eur J Ophthalmol*. 1995;5:240–246.
28. Lincoff HA, Kreissig I, Hahn YS. A temporary balloon buckle for the treatment of small retinal detachments. *Ophthalmology*. 1979;86:586–592.
29. Kreissig I, Failer J, Lincoff H, Ferrari F. Results of a temporary balloon buckle in the treatment of 500 retinal detachments and a comparison with pneumatic retinopexy. *Am J Ophthalmol*. 1989;107:381–389.
30. Kreissig I. *A Practical Guide to Minimal Surgery for Retinal Detachment: Vol. 2. Temporary Tamponades with Balloon and Gases without Drainage, Buckling versus Gases versus Vitrectomy, Reoperation, Case Presentations*9. Stuttgart: Thieme; 2000:2–107.
31. Norton EWD. Intraocular gas in the management of selected retinal detachments. *Trans Am Acad Ophthalmol Otolaryngol*. 1973;77:OP85–OP98.
32. Lincoff H. Reply to Drs Fineberg, Machemer, Sullivan and Norton. *Mod Probl Ophthalmol*. 1974;12:344–345.
33. Kreissig I. Clinical experience with SF_6-gas in detachment surgery. *Berichte der Deutschen Ophthalmologischen Gesellschaft*. 1979;76:553–560.
34. Kreissig I, Stanowsky A, Lincoff H, Richard G. Treatment of difficult retinal detachments with expanding gas bubble without vitrectomy. *Graefes Arch Clin Exp Ophthalmol*. 1986;224:51–54.
35. Kreissig I. The expanding-gas operation after 15 years: Data of animal experiments, subsequent modifications of the procedure and clinical results in the treatment of retinal detachments. *Klin Mbl Augenheilk*. 1990;197:231–239.
36. Lincoff A, Haft D, Liggett P, Reifer C. Intravitreal expansion of perfluorocarbon bubbles. *Arch Ophthalmol*. 1980;98:1646.
37. Lincoff H, Maisel JM, Lincoff A. Intravitreal disappearance rates of four perfluorocarbon gases. *Arch Ophthalmol*. 1984;102:928–929.
38. Hilton GF, Grizzard WS. Pneumatic retinopexy. A two-step outpatient operation without conjunctival incision. *Ophthalmology*. 1986;93:626–641.
39. Dominguez A, Fonseca A, Gomez-Montana J. Gas tamponade for ambulatory treatment of retinal detachment. In: *Proceedings of the XXVth International Congress of Ophthalmology. Rome, May 4-10, 1986*. Amsterdam: Kugler & Ghedini; 1987:2038–2045.
40. Machemer R, Buettner H, Norton EWD, Parel JM. Vitrectomy: a *pars plana* approach. *Trans Am Acad Ophthalmol*. 1971;75:813–820.
41. Lincoff H, Lincoff A, Stopa M. Systemic review of efficacy and safety of surgery for primary retinal detachment. In: Kreissig I, ed. *Primary Retinal Detachment: Options for Repair*. New York: Springer; 2004:161–175.
42. Feltgen N, Weiss C, Wolf S, Ottenberg D, Heimann H, SPR Study Group. Scleral buckling versus primary vitrectomy in rhegmatogenous retinal detachment study (SPR Study): recruitment list evaluation. Study report no. 2. *Graefes Arch Clin Exp Ophthalmol*. 2007;245:803–809.
43. Heimann H, Bartz-Schmidt KU, Bornfeld N, et al. Scleral buckling versus primary vitrectomy in rhegmatogenous retinal detachment: a prospective randomized multicenter clinical study. *Ophthalmology*. 2007;114:2142–2154.
44. Tornambe PE. Pneumatic retinopexy: the evolution of case selection and surgical technique. A twelve-year study of 302 eyes. *Trans Am Ophthalmol Soc*. 1997;95:551–578.
45. Eckardt C. Transconjunctival sutureless 23-gauge vitrectomy. *Retina*. 2005;25:208–211.
46. Sakaguchi H, Oshima Y, Tano Y. 27-gauge transconjunctival nonvitrectomizing vitreous surgery for epiretinal membrane removal. *Retina*. 2007;27:1302–1304.