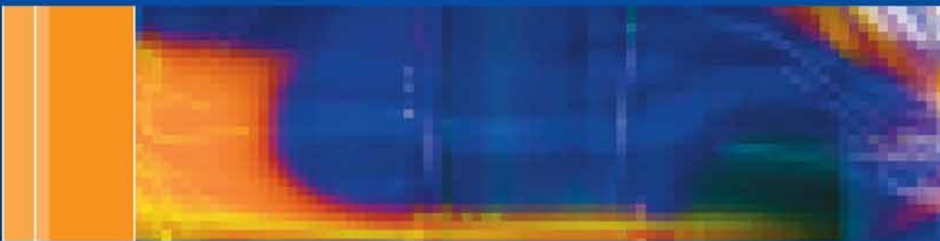
Ingrid Kreissig *Editor*



Primary Retinal Detachment

Options for Repair

Springer

Ingrid Kreissig (Ed.)

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Options for Repair

With 55 Figures, Mostly in Color
and 20 Tables

Springer

Professor Dr. med. Ingrid Kreissig
Department of Ophthalmology
Faculty of Clinical Medicine Mannheim
University of Heidelberg
Theodor-Kutzer-Ufer 1–3
68167 Mannheim, Germany

Adjunct Professor of Clinical Ophthalmology
The Weill Medical College of Cornell University
New York, USA

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Preface

I wish to express my gratitude to the experts in retinal and vitreous surgery who were generous enough to provide chapters for this book.

The book aims to enable the retinal and vitreous surgeon to participate in the ongoing discussion regarding the best surgical technique for primary retinal detachment. The chapters of the book are written by experts in the field. Four separate chapters describe the four principle techniques available for repair of primary retinal detachment at the beginning of the twenty-first century. Attention is given to pharmaceutical interventions that might improve surgical outcome.

Each of the four surgical techniques can be successful in the hands of an expert on the procedure. The difference lies in postoperative morbidity, rate of reoperation and long-term visual function.

Chapter 9 takes up the preceding chapters and presents an example of a primary three quadrant detachment with one break treated by each of the four surgical techniques. The reader is invited to draw his or her own conclusion about which procedure is the better one and what to do and what not to do.

The last chapter, subtitled "Outlook for the Future", represents speculation about future developments in the field of retinal detachment surgery.

The book is intended as a "hands-on" guide for the retina and vitreous surgeon who is confronted with a primary retinal detachment and wishes to select a surgical technique with a minimum of morbidity and an optimum of long-term visual outcome.

Contents

List of Contributors

Gary W. Abrams, M.D.
Professor and Chair, Department of Ophthalmology, Wayne State University, Director, Kresge Eye Institute, 4717 St. Antoine, Detroit, MI 48201, USA

Mark S. Blumenkranz, M.D.
Professor and Chairman, Department of Ophthalmology, Stanford University, Med. Center, 300 Pasteur Drive, Room A157, Boswell Building, Stanford, CA 94305, USA

Norman E. Byer, M.D.
Clinical Professor of Ophthalmology Emeritus
UCLA School of Medicine, Los Angeles
P.O. Box 1036, Torrance, CA 90505, USA

Stanley Chang, M.D.
Edward Harkness Professor and Chairman
KK Tse and Ku Teh Ying Professor of Ophthalmology,
Department of Ophthalmology, Columbia University,
635 West 165th Street, New York, NY 10032, USA

William R. Freeman, M.D.
Professor of Ophthalmology
Director Joan and Irwin Jacobs Retina Center,
UCSD Department of Ophthalmology,
Shiley Eye Center, University of California San Diego,
9415 Campus Point Drive, La Jolla, CA 92093-0946, USA

Eric R. Holz, M.D.
Cullen Eye Institute, Baylor College of Medicine,
6565 Fannin, NC-205 Houston, TX 77030, USA

Ingrid Kreissig, M.D.
Professor of Ophthalmology, University Mannheim/Heidelberg,
Theodor-Kutzer Ufer 1-3, 68167 Mannheim, Germany

Adjunct Professor of Clinical Ophthalmology,
Weill Medical College of Cornell University
The New York Presbytarian Hospital, New York, NY 10021, USA

Anne Lincoff, M.D.
Department of Ophthalmology,
Weill Medical College of Cornell University
The New York Presbytarian Hospital,
525 East 68th Street, New York, NY 10021, USA

Harvey Lincoff, M.D.
Professor of Ophthalmology,
Weill Medical College of Cornell University
The New York Presbytarian Hospital, 525 East 68th Street
New York, NY 10021, USA, Newhouse Clinical Scholar

William F. Mieler, M.D.
Professor and Chairman,
Department of Ophthalmology and Visual Science
University of Chicago, 5841 So. Maryland,
MC 2114 Chicago, Illinois 60637, USA

Kourous A. Rezaei, M.D.
Head of Vitreoretinal Service,
Department of Ophthalmology and Visual Science
University of Chicago, 5841 So. Maryland,
MC 2114 Chicago, Illinois 60637, USA

Hermann D. Schubert, M.D.
Professor of Clinical Ophthalmology and Pathology,
Columbia University New York
E. S. Harkness Eye Institute,
635 W 165th Street, New York, NY 10032, USA

Marcin Stopa, M.D.
Department of Ophthalmology,
Weill Medical College of Cornell University
The New York Presbytarian Hospital
525 East 68th Street, New York, NY 10021, USA

The History of Retinal Detachment Surgery

Kourous A. Rezaei, Gary W. Abrams

The history of retinal detachment surgery is one of the great success stories in the history of medicine. The first descriptions of retinal detachment were by Ware in 1805, Wardrop in 1818, and Panizza in 1826 [1–3]. These descriptions relied mainly on pathological observations. The introduction of the ophthalmoscope by

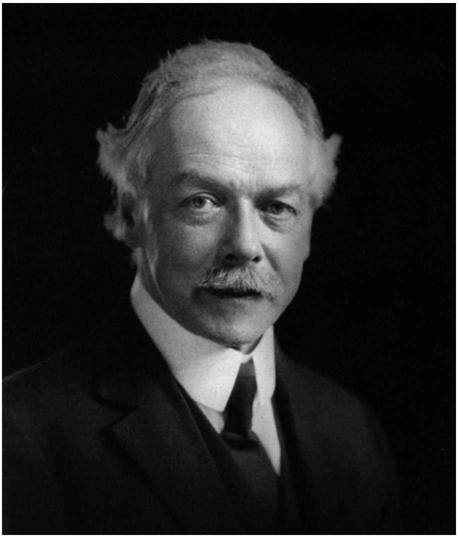

Fig. 1.1. Jules Gonin. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

Helmholz in 1850 made an accurate and reliable clinical diagnosis possible [4]. Coccius in 1853 followed by von Graefe in 1854, who also portrayed the course of retinal detachment, observed the first retinal tear [5, 6]. The history of retinal detachment surgery can be divided into pre- (before 1920) and post-Jules Gonin's era (after 1930).

In 1920, Gonin reported the first successful treatment of retinal detachment by sealing the retinal break to the underlying retinal pigment epithelium (RPE) and the choroid (Fig. 1.1) [7, 8]. During and after the time of Gonin's contributions, many surgeons contributed to the advancement and success of retinal surgery. Prior to this time, however, there was little or no successful treatment for retinal detachment but a large number of treatments were proposed and are mentioned here for historical interest. Some of this work has been adapted from the great historical collection of Duke Elder's *System of Ophthalmology* and from Michels' *Retinal Detachment* [9, 10].

Pre-Gonin Era

Medical Treatment of Retinal Detachment

Stellwag in 1861 and Donders in 1866 proposed rest as essential for treatment of retinal detachment [11, 12]. By rest, it was meant the immobility of the body and the eyes, with the latter being the more important component; both eyes were bandaged, atropine was applied for intraocular immobility, and complete immobility of the body was achieved by laying on the back with the head sandwiched between sandbags. Samelsohn in 1875 suggested compression bandaging combined with rest for many weeks [13]. Mendoza in 1920 recommended a plaster mould that would fit the eye and the orbital ridges and therefore apply even pressure to the eye [14]. Further, Marx in 1922 advised a salt-free diet to promote the absorption of subretinal fluid [15].

Surgical Treatment of Retinal Detachment

The first operation attempted for treatment of retinal detachment was by James Ware in 1805 who drained the subretinal fluid by puncturing the sclera with a knife [16]. In 1863, von Graefe modified this method by also puncturing the retina and creating a second hole for the drainage of the subretinal fluid into the vitreous cavity [17]. G. Martin in 1881 and de Wecker in 1882 introduced the thermo-cautery (later popularized by Dor (1895–1907) as the method of puncture [18–20]).

Permanent drainage of subretinal fluid using trephining was advocated by de Wecker in 1872 and Argyll Robertson in 1876 [21, 22]. The introduction of Elliot's operation for glaucoma popularized trephining between 1915 and 1920 [9]. Groenholm in 1921 advocated the Holt pre-equatorial sclerectomy: the removal of a large disc of sclera so that the suprachoroidal space is in communication with subtenon's space [23]. In 1924, Wiener made two trephine holes 1 mm apart and threaded a strand of horse-hair into one hole and out of the other [24].

There were numerous other surgical methods attempted for retinal detachment. Subconjunctival injections were first suggested by Grossman in 1883 and then popularized by Mellinger in 1896 who used hypertonic saline to extract the subretinal fluid by osmotic forces [25, 26]. Division of vitreous fibers to treat retinal detachment was attempted by Deutschmann in 1895 [27]. Reduction of the globe capacity on the basis of von Graefe's theory that the cause of detachment was an increase in the volume of the eye in myopia was advocated by Leopold Mueller in 1903 [28]. Torok collected reports of 50 such procedures and found that none had permanent success [29]. Raising the intraocular pressure was advocated, postulating that the retina would be re-apposed by the high pressure in the eye. Lagrange in 1912 introduced colmatage, whereby triple rows of cautery were made underneath a conjunctival flap [30]. Carbone in 1925 recommended the injection of material (vitreous, gelatin) into the anterior chamber to raise the intraocular pressure [31]. Others attempted to push the retina back towards the choroid by injecting various materials into the vitreous cavity. Deutschmann injected rabbit vitreous in 1895, Nakashima injected protein solutions in 1926, and Ohm (1911), Rohmer (1912), Jeandelize and Baudot in 1926, and Szymanski in 1933 injected air [27, 32–36]. Meyer in 1871 attempted suturing of the retina to an opening in the scleral wall and Galezowski in 1890 practiced suturing the retina to the choroid [37, 38].

Many possible methods of retinopexy were attempted (cautery, electrolysis, and injection of irritant substances under the retina); however, they were all unsuccessful since there was no attention given to the closure of retinal breaks.

Although many procedures were proposed for the treatment of retinal detachment, the success rate was low. In 1912, Vail surveyed the ophthalmologists in the United States to report their success rate in treating retinal detachment. He concluded that the success rate was 1 in 1,000 and that the treatment modalities were ineffective [39].

Post-Gonin Era

Among many competing theories on the cause of retinal detachment prior to Gonin were suggestions that retinal breaks were necessary for the retina to detach and vitreous traction caused retinal breaks. de Wecker in 1870 argued that "retinal ruptures" were necessary for fluid to pass beneath the retina to cause a retinal detachment [40]. He subscribed to Iwanoff's theory that distention of the eye, caused by exudation of fluid behind the vitreous, led to development of the ruptures [40]. Leber and Nordenson in 1882 and 1887, respectively, originated the vitreous retraction or shrinkage theory. They thought that retraction of the shrinking vitreous placed traction on the anterior retina that caused tearing of the retina. They theorized that serous vitreous fluid then entered through the tears into the subretinal space to detach the retina. The major contribution of Jules Gonin was to show that retinal breaks are the main cause of retinal detachments and that successful reattachment of retinas was dependent on the sealing of such breaks [7, 8, 41]. His procedure required a meticulous retinal examination and search for breaks. In 1918, he told the Swiss Ophthalmologic Society that the cause of idiopathic retinal detachment was the development of retinal tears due to tractional forces caused by the vitreous [42, 43]. In 1920, he reported to the French Ophthalmologic Society that he had cured retinal detachments by application of cautery to the sclera over retinal breaks (first operations in 1919) [8]. Many did not believe him. In 1929, at the International Congress of Ophthalmology in Amsterdam, Gonin (along with his disciples Arruga, Weve, and Amsler) conclusively proved to his audience that retinal breaks were the cause of retinal detachment and that closure of retinal breaks caused the retina to reattach [42, 43]. During Gonin's era, the success rate exceeded 50%. At this time, many procedures were proposed which we will summarize here from the historical standpoint.

Gonin's original procedure was to accurately localize the retinal break on the sclera [44]. Localization required estimating the distance of the break from the ora serrata in disc diameters, multiplying that figure by 1.5, then adding 8 mm to determine the distance of the break from the limbus. After measurement in the meridian of the break, a Paquelin thermocautery, heated till becoming white, was inserted into the vitreous. When the needle was withdrawn, there was drainage of subretinal fluid and incarceration of the edges of the break in the drainage site. In successful cases, there was subsequent closure of the edges of the break in the drainage site. During this procedure, subretinal fluid was sometimes only partially drained and he observed that, if breaks were sealed, the residual fluid would usually absorb. The majority of procedures for the next 20 years were variants of Gonin's operation with modifications in the method of treatment of breaks and the method of drainage. Significant advances were the use of intraocular air to close retinal breaks and the early experimentation with scleral resection that set the stage for scleral buckling procedures [45–50].

Modern surgical techniques for repair of retinal detachment have evolved from the methods developed by pioneers who first learned to close retinal breaks. These techniques can be mainly divided into retinopexy, scleral buckling, vitreous surgery, and intraocular tamponade.

Retinopexy

Many techniques were proposed for the creation of chorioretinal adhesions. Diathermy became the worldwide standard for retinopexy until the adoption of cryopexy in the 1960s. However, other methods were transiently used. In 1931, Guist cauterized the choroid around the break by touching it with a caustic potash stick in several places after it had been exposed with trephine openings through the sclera and the subretinal fluid drained [51]. This method was further modified by Lindner [52]. Passage of a galvanic electric current to produce a chorioretinal scar was proposed by Imre in 1930 followed by von Szily and Helmut Machemer in 1934 [53–55].[1] The technique of diathermy was originally proposed by Larsson, Weve, and Safar and was further modified by Walker who developed a small, compact diathermy device [56–59]. Later, Weve employed both surface and puncture applications by unipolar electrodes while viewing with an indirect ophthalmoscope. Three methods of diathermy were utilized: (1) surface diathermy followed by drainage of subretinal fluid, (2) penetrating diathermy with drainage of subretinal fluid through the needle tracts, and (3) partial penetrating or surface diathermy with penetrating applications (the penetrating applications were used for drainage and were surrounded by non-penetrating applications) [10]. Dellaporta

[1] Helmut Machemer was the father of Robert Machemer, the originator of vitreous surgery.

in 1954 closed retinal breaks with intraocular diathermy through the pars plana; he used a needle that was insulated except at its tip [60]. Although diathermy alone (with or without drainage of subretinal fluid) was the treatment of choice for retinal detachment prior to 1950, between 1955 and 1960, in most cases an indentation by a scleral buckle or scleral resection was added [61].

Light photocoagulation was first described by Czerny in 1867 who used a concave mirror and convex lens to focus sun light to induce retinal burns in animals [62]. Maggiore, in 1927, did the first experimental photocoagulation of the human retina when he focused sunlight for 10 min on the retina of a patient prior to enucleation for a malignant tumor [63]. Moran-Sales first used photocoagulation therapeutically in humans; however, Meyer-Schwickerath, in 1949, was the first to publish this technique [64, 65]. Due to his pioneering work, Meyer-Schwickerath is considered the father of photocoagulation. His work originated from his observation of chorioretinal scars secondary to eclipse burns [64]. He first tried to photocoagulate the retina with a carbon arc lamp and, then, through a series of mirrors and lenses with the sun as the source of light [66]. In cooperation with Hans Littmann, he subsequently developed a xenon-arc photocoagulation system that became available in 1958 and was used for the next 15 years. Following the development of the first laser (the ruby laser) in 1960 by Maiman, Zaret, in 1961, first published his experience with ruby laser photocoagulation of the animal iris and retina [67, 68]. Campbell and coworkers, in 1963, first reported ruby laser photocoagulation of the human retina [69]. They treated a retinal tear with a combination of ruby laser and xenon-arc photocoagulation. Argon laser treatment in humans was first reported in 1969 by L'Esperance followed by Little et al. in 1970 [70, 71]. At this time, point argon laser widely replaced xenon photocoagulation for treatment of retinal diseases.

Cryotherapy was introduced in 1933 by Deutschmann, who used solid carbon dioxide snow, and Bietti (1933–34), who used a mixture of this substance with acetone, to induce adhesive choroiditis [72–74]. Temperatures up to –80°C could be reached using this technique. Three decades later in 1961, cryotherapy was re-introduced for intracapsular removal of cataracts by Krwawicz [75]. The cooling mechanism was a mixture of alcohol and solid carbon dioxide. In 1963, Kelman and Cooper created cryogenic chorioretinal scars in rabbits using a cryosurgical unit designed for treatment of neurological movement disorders that utilized liquid nitrogen to reach temperatures as low as –196°C [76]. Lincoff and coworkers, in 1964, using a similar neurosurgical Cooper-Linde cryosurgical unit, designed and built a probe for trans-scleral treatment of retinal diseases that would produce temperatures as low as –90°C [77]. In experimental work in animals and early experience in humans, they found that –20°C to –40°C were the required temperatures for clinical use. Lincoff first treated humans with cryopexy in 1963, and reported the following year on his first 30 cases with retinal tears with or without retinal detachment [77]. Lincoff observed that cryotherapy did not cause scleral complications, such as those seen following diathermy application to full-thickness sclera, and led the popular transition from diathermy to cryotherapy for retinal detachment repair. Smaller, lighter, less-complicated instruments for cryopexy that are safe and easily maintained were developed that use the Joule-Thomson effect in cooling of gases such as nitrous oxide or carbon dioxide [78].

Scleral Buckling

Mueller introduced shortening of the sclera in 1903 for reducing the volume of the globe [79]. Lindner, in 1931, revived this technique by performing a perforating sclerectomy and removing a meridional section of sclera [9]. Due to its difficulty and high complication rate it was replaced by lamellar scleral resection that was originally introduced by Blascovics in 1912 and later popularized by Shapland (1951–1953), Dellaporta (1951–1957), and Paufique (1952) [47, 48, 61, 80, 81]. Using this technique, two-thirds of the out-

Fig. 1.2. Ernst Custodis. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

er sclera over the retinal breaks was dissected in a circumferential direction and removed. The edges were opposed with sutures and the inversion of the scleral bed caused by the sutures created a sclero-choroidal ridge. Diathermy was applied to the retinal hole, but was later replaced by cryotherapy or photocoagulation. This procedure not only induced shortening of the sclera but also induced a buckling effect that led to the later development of encircling scleral buckles.

In 1937, Jess was the first to use a foreign substance to create a scleral buckle when he inserted a temporary tampon of gauze beneath Tenon's capsule over the retinal break [82]. Lindner in 1949 and Weve in 1949–1950 used a reefing stitch in the sclera to induce a similar effect [83, 84]. The first scleral buckling procedure with a retained exoplant was performed by Custodis in 1949 (Fig. 1.2) [85].

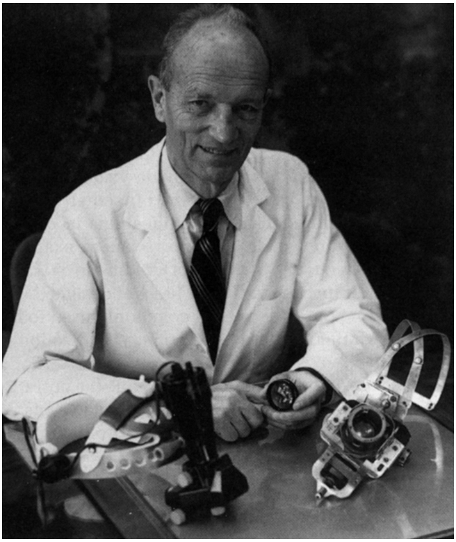

Fig. 1.3. Charles L. Schepens. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

After applying surface diathermy to the full-thickness sclera over the break, he sutured a polyviol material to the sclera. The eye wall was indented at the area of the break so that the retina would appose the RPE and close the break. In 1956, he reported his experience with 515 consecutive patients with an 83.3% successful reattachment rate [85]. He did not believe that subretinal fluid needed to be drained and, if the subretinal fluid was not absorbed by day 4, he recommended re-operation. Schepens in 1951 performed the first scleral buckling procedure with an exoplant in the United States (Fig. 1.3) [86–93]. In 1956, he described the use of an encircling polyethylene tube that was placed under the flap of a lamellar scleral dissection [88]. Using the indirect ophthalmoscope introduced by Schepens, he and his colleagues were able to identify and meticulously localize the posterior edge of retinal breaks [94]. The midpoint of the scleral dissection was slightly posterior to the breaks and surface diathermy was placed in the bed of the lamellar dissection along this line at the posterior edge of the breaks and extended anterior, at each end of the retinal detachment. The goal of the operation was to form a permanent barrier with the buckle and the diathermy-induced adhesion to prevent residual anterior subretinal fluid from extending posteriorly. Contrary to the practice of Custodis, Schepens and his colleagues would drain the subretinal fluid. The rigid polyethylene tubes, though effective, sometimes eroded through the sclera into the eye. Schepens further modified the scleral buckling procedure using silicone rubber implants, originally recommended by McDonald, that were less likely to erode because they were softer and less rigid than the polyethylene tubes, but retained the barrier concept [93]. Because the anterior edge of the breaks often remained open, subretinal fluid would sometimes leak anteriorly and extend through the barrier to detach the posterior retina. Their next step was to modify the encircling procedure to close the retinal breaks. In 1965, Brockhurst and colleagues described the now-classic scleral buckling technique of lamellar dissection, diathermy of the scleral bed, and the use of silicone buckling materials of various shapes, widths and thicknesses in conjunction with an encircling band to close the breaks [95].

In 1965, Lincoff modified the Custodis procedure using silicone sponges instead of polyviol explants, better needles for scleral suturing, and cryopexy instead of diathermy (Fig. 1.4) [96]. Lincoff became the major advocate of non-drainage procedures and led the movement from diathermy to cryotherapy for retinopexy. By Kreissig in subsequent years, the non-drainage technique with segmental buckling was further refined to so-called minimal surgery for retinal detachment [97].

A number of absorbable materials, such as sclera, gelatin, fascia lata, plantaris tendon, cat gut, and collagen were introduced [98–108]. However, some absorbable materials were complicated by erosion, intrusion, and infection and none is currently used. Silicone rubber and silicone sponges have proven reliable and safe for

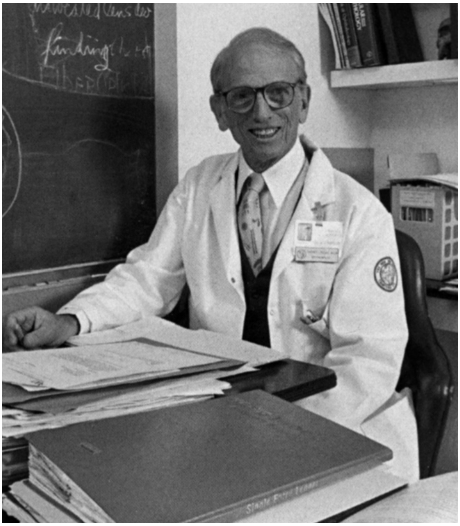

Fig. 1.4. Harvey Lincoff. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

many years and are the standard for scleral buckles. However, another material that was used for scleral buckles proved problematic. A form of hydrogel, co-poly (methylacrylate-2-hydroxyethyl acrylate) (MAI) (Miragel) can undergo microstructural change of the architecture of the porous material when left in place for 5 years or more and require removal [109]. MAI can swell, fragment and cause a granulomatous foreign body reaction. A patient can develop irritation, disturbance of ocular motility, an extraocular mass and rarely intrusion of the buckle through the sclera. It has been necessary to remove many MAI scleral buckles.

Vitreous Surgery

Von Graefe and Deutschmann were the first clinicians to advocate cutting vitreous and/or retina in order to treat retinal detachment; however, they did not cut vitreous gel, but mainly cut vitreous membranes with a knife [17, 110]. Von Hippel in 1915 cut a vitreous membrane and successfully treated a tractional retinal detachment [111]. The first modern intraocular instruments, made specifically for cutting vitreal membranes, were developed in the second half of the twentieth century. Neubauer in 1963 described intravitreal scissors that were activated by finger pressure [112, 113]. Cibis in 1965 devised a tissue cutter that consisted of a hook and a trephine [114]. Kasner in 1962 was the first to advocate open-sky vitrectomy to remove vitreous gel for the treatment of eye diseases [115–118]. Kasner engaged the vitreous with cellulose sponges and cut it with scissors. He proved that the eye can tolerate the removal of the vitreous gel. Stimulated by the pioneering work of Kasner, Robert Machemer initiated and developed closed vitreous surgery (Fig. 1.5) [119–121]. He and Parel developed instruments that could, through the pars plana, suction and cut vitreous and infuse replacement fluid all in one single probe [122]. His original instrument was called the VISC (Vitreous Infusion Suction Cutter). Machemer performed the first pars plana vitrectomy in April 1970 and first published the technique in 1971 [119]. In a remarkable series of publications from 1971–1976, Machemer and coworkers described the original instrumentation and technique, initial indications and results, new instrumentation, and expanded indications, techniques (such as bimanual dissection techniques and relaxing retinectomy), and results [123–134]. Independently, Peyman et al. reported their experience with vitrectomy in 1971 [135]. The next step in the development of the instrumentation was reduction of the diameter of the probes by separation of the infusion, the endo-illumination, and cutting/aspiration probes. The Ocutome system was introduced by O'Malley and Heintz in 1975 [136]. Another milestone in vitreous surgery was improvement in the operating microscope.

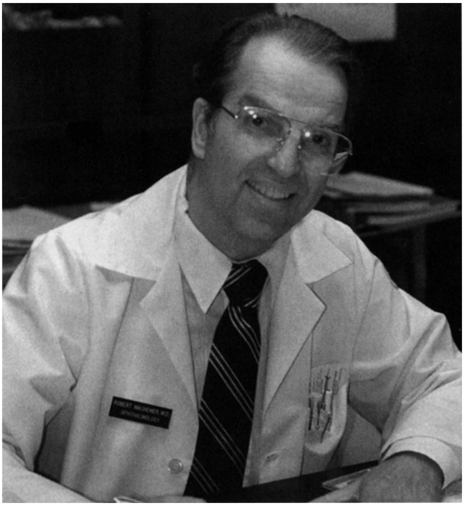

Fig. 1.5. Robert Machemer. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

Littmann in 1954 first described a telecentric device with a paraxial illumination source [137]. Parel et al. in 1974 developed an operating microscope with foot control and X-Y movement that led to the development of the modern operating microscope [129]. Many different intraocular instruments, infusion systems, and illumination sources have been developed. Vitrectomy is now the standard treatment for many forms of retinal detachment including traction retinal detachment, retinal detachment due to giant retinal tears, any retinal detachment associated with opaque vitreous, retinal detachment with posterior retinal breaks (including macular holes), proliferative vitreoretinopathy, and other forms of complicated retinal detachment. Although studies have yet to show a conclusive advantage, some surgeons favor vitrectomy over other methods for repair of primary retinal detachments [138].

Intraocular Tamponade

Another technique to help appose retina and choroid that could be used in conjunction with other procedures was injection of air into the vitreous cavity. Originally described by Ohm in 1911 and then by Rohmer in 1912, injection of air at the end of the operation was adopted by Arruga in 1935, and to close retinal breaks by Rosengren in 1938 [32, 34, 139]. Rosengren carefully localized retinal breaks, then placed penetrating diathermy in a pattern covering an area 6–7 mm in diameter with drainage of subretinal fluid. He injected air into the vitreous cavity, then positioned the patient postoperatively such that the air bubble closed the retinal breaks and apposed the retina to the RPE. Rosengren reported successful retinal reattachment in 75% of 300 cases with the technique [45].

Later Norton concluded that large breaks may respond better to tamponade by air than by a scleral buckle alone; however, air did not persist long enough in the eye [140]. He introduced sulfur hexafluoride (SF6) gas for internal tamponade of retinal breaks. Pure SF6 expands approximately twice its injected volume in the eye and persists twice as long as a comparable air bubble. Inert perfluorocarbon gases, introduced by Vygantas (C4F8) and Lincoff (C2F6, C3F8, C4F10), expanded more and lasted even longer than SF6 in the eye [141, 142].

Cibis in 1962 was the first to report the use of silicone oil for treatment of retinal detachment [143]. The complications of silicone oil made its usage unfavorable at that time. Haut in 1978 introduced the use of silicone oil with vitrectomy [144]. Zivojnovic became the major advocate of silicone oil in combination with "retinal surgery" (relaxing retinectomy) to treat severe proliferative vitreoretinopathy and traumatic retinal detachments [145]. Parke and Aaberg first reported the technique of argon laser endophotocoagulation in conjunction with vitrectomy, retinectomy, and intraocular gas for the management of PVR [146]. Development of air pumps was also an important landmark, so retinas could be reattached with a fluid-air exchange in a controlled fashion [147]. Perfluorocarbon liquids which were originally evaluated as blood substitutes were first used as a vitreous substitute by Haidt in 1982 [148]. Chang later popularized the use of perfluorocarbon liquids for the clinical management of certain types of retinal detachments and giant tears [149, 150].

Retinal detachment surgery has come a long way since it was first successfully performed by Gonin. The past 50 years mark the evolution of this surgery, reaching success rates of 90% or higher. The future of retinal surgery most likely will be reduction in the morbidity of surgery and improving the visual outcome in eyes with successfully reattached retinas.

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Prophylaxis in Fellow Eye of Primary Retinal Detachment: What Not to Do and What to Do

Norman Byer

It is generally very helpful in understanding the present to make a retrospective survey of the thinking of the past, which has led us to our present concepts. The progression of ideas in the case of prophylactic treatment of retinal detachment first developed from a few correct elementary clinical observations, but then proceeded on the basis of mostly theoretical reasoning because of the profound dearth of empirical data.

Along with the early realization that some retinal detachments could be successfully treated, other observations also began to be made. Certain associated pre-existing retinal lesions began to be observed in eyes in which causative retinal tears had led to retinal detachment. It was thought that perhaps these associated lesions were responsible for the onset of the retinal tears and, therefore, were of prognostic importance. With the advance of more careful retinal examination, more of these lesions began to be discovered in the "fellow eyes" of patients who had had a retinal detachment in their primary eyes and also in the eyes of patients who had not suffered a retinal detachment.

The idea soon began to be entertained that perhaps retinal detachments could be prevented, in the first instance, by "treating" these associated lesions before the initiating retinal tears occurred. Because natural history information regarding these various retinal lesions was almost non-existent at that time, the concept of the value of such "prophylactic" treatment rested on purely theoretical reasoning. This gulf between theoretical expectations and actual empirical data was easily, and unknowingly, bridged by several broad assumptions which were as follows: (1) the occurrence of bilateral retinal detachment was thought to be in the range of 20–50% of patients who had suffered a primary detachment, (2) the associated pre-existing "suspect" retinal lesions were thought to represent the precursor sites from which retinal tears would later arise, and (3) the pretreatment of these pre-existing visible retinal lesions was thought to prevent later retinal tears and detachment.

This thinking, which was believed to justify the concept of "prophylactic" treatment, was greatly advanced and crystallized in the 1950s by the bringing together of two important developments in ophthalmology. The first of these was the popularization by Schepens [1] of a definitive method of retinal examination, using binocular indirect ophthalmoscopy combined with simultaneous localized scleral indentation. This method opened the possibility of examining in detail all areas of the retina in multiple, stereoscopically viewed images. This development was a vast advance over previous methods and eventually led to the accurate characterization of various peripheral retinal lesions and to the quantitative collection of natural history data that had previously remained unknown.

The second very significant event that influenced the thinking regarding "prophylactic" treatment was the invention by Meyer-Schwickerath [2] of an effective method to deliver controlled photocoagulation energy to the retina to produce discrete retinal burns which later became converted into small scars.

The concurrence of these two events had the momentous effect of opening up the vastly improved possibilities of finding and of treating many peripheral retinal lesions which heretofore had remained hidden. In a relatively short time, as the result of very successful promotion and distribution, photocoagulation instruments became available throughout the world. It is very easy to understand, based on the uncritical acceptance of the previously mentioned three assumptions, that a new "standard of care" soon emerged throughout the world that prevention of retinal detachment could (and should) be achieved by systematic "prophylactic" treatment of various pre-existing asymptomatic retinal lesions.

Two large long-term surveys of reports in the literature, purporting to substantiate the correctness of this view were published by Meyer-Schwickerath and Fried in 1980 [3] and by Haut et al. in 1988 [4] all of whom were staunch advocates of this standard of care and believed that it provided substantial success in achieving the goal of preventing retinal detachment. Both surveys revealed that there was a residual risk of retinal detachment, even after those attempts to prevent it, amounting to 5% in the first report [3] and 2–5.5% in the second report [4], depending on the modality used.

Eventually, however, various reports began to appear which tended to agree in showing that the three underlying assumptions which formed the basis of the new standard of care were not accurate. With regard to the first assumption, the bilaterality of retinal detachment had been considerably overestimated, and instead of being 20–50%, was in the range of 6–11% [5–13] (Table 2.1).

With regard to the second assumption, it has been reported that 72% of new symptomatic retinal tears occur in retinal areas that appear clinically normal [14]; and, in a large autopsy study of eyes

Table 2.1. Incidence of bilateral retinal detachment

Author(s)	Incidence (%)
Toernquist 1963 [5]	11.2
Edmund 1964 [6]	9.3
Boeke 1966 [7]	6.6
Michaelson et al. 1969 [8]	10.9
Davis et al. 1974 [9]	7.9
Bleckman and Engels 1975 [10]	8.1
Haut and Massin 1975 [11]	11.4
Laatikainen and Harju 1985 [12]	10.0
Toernquist et al. 1987 [13]	11.0

Table 2.2. Remaining risk of retinal detachment (RD) following "prophylactic" treatment of fellow eyes with predisposing lesions

Author(s)	Risk of RD (%)
Michaelson et al. 1972 [16]	9.1
Morax et al. 1974 [17]	8.6
Dralands et al. 1980 [18]	2.9
Meyer-Schwickerath and Fried 1980 [3]	5.0
Girard et al. 1982, 1983 [19, 20]	4.4
Haut et al. 1988 [4]	2.0–5.5
Folk et al. 1989 [21]	2.9

Table 2.3. Incidence of retinal detachment in fellow eyes of comparison groups of patients with "dangerous" lesions without and with "prophylactic" treatment

Author(s)	Without Rx (%)	With Rx (%)
Dralands et al. 1980 [18]	3.7	2.9
Girard et al. 1982, 1983 [19, 20]	0.0	4.4
Folk et al. 1989 [21]	5.1	2.9

with lattice degeneration, 79% of the tears were located in such areas [15].

As for the third assumption, various reports have shown the still remaining rate of detachment following "prophylactic" treatment of fellow eyes to be from 2% to 9% [3, 4, 16–21] (Table 2.2).

It is especially helpful in this discussion to present data reported by authors who compared two parallel groups of patients – one being treated and one not being treated [18–21]. These are summarized in Table 2.3.

This led Michaelson et al. [16] to say that "no notable drop in fellow eye detachment had occurred", and they officially discontinued the practice of "prophylactic" treatment. Dralands et al. [18]

also concluded that "the incidence of second eye detachments does not decrease as the result of preventive treatment". These data are summarized in Table 2.2.

The special category of aphakic or pseudophakic fellow eyes has very little pertinent data from comparative studies in the literature comparing treated and untreated groups. However, such a study was reported in 1989 by Herzeel et al. [22] in which one of the groups was treated with encircling circumferential cryotherapy. They found that the treated group developed retinal detachment in 2.3%; whereas, this outcome occurred in only 1.3% of the untreated group, leading the authors to say that "these results lead us to conclude that 'prophylactic' treatment does not necessarily prevent this complication".

A further category of fellow eyes that simultaneously harbor multiple risks has always represented a special group which has been thought to have a more marked vulnerability to detachment and therefore to be pre-eminently eligible for "prophylactic" treatment. However, Folk et al. [21] in 1989 reported comparison groups of fellow eyes, all of which had three simultaneous risk factors for retinal detachment (fellow eye status, lattice degeneration and high myopia). They found that "prophylactic" treatment of the lattice lesions did not confer any advantage in lowering the rate of detachments. Instead, apparently what happens is that, although the risk of detachment is higher with existing multiple risk factors, so also is the risk of secondary detachment following treatment.

In fact the incidence of retinal detachment following "prophylactic" treatment is in approximately the same range as the rate of detachment in fellow eyes left untreated.

Therefore, we may conclude that the earlier hope of preventing retinal detachment in fellow eyes by some form of "prophylactic" treatment has not been significantly substantiated, and this approach offers no more than a slight benefit.

The significant visible predisposing lesions of the peripheral retina, related to retinal detachment, which are primarily lattice degeneration, senile retinoschisis, retinal breaks, and cystic retinal tufts also have a significant prevalence rate in primary eyes. Here, also the natural histories as well as the futility of applying so-called "prophylactic" treatment has been amply documented [23–26].

In summary, we may say that the well-established practice of applying "prophylactic" treatment to visible predisposing peripheral retinal lesions, whether in primary eyes or in fellow eyes, before any detachment has occurred, and specifically for the purpose of preventing this outcome has by now been thoroughly discredited and must be discarded as the "standard of care". This answers the first major question of this chapter, and constitutes, "What NOT to do".

This does not mean however that retinal detachments cannot be prevented. However, our clinical attention must be directed to a completely different matter. We should not treat asymptomatic eyes (whether primary or fellow eyes), but we should be on the lookout for patients who complain of recent visual symptoms that suggest the occurrence of a posterior vitreous detachment. Such symptoms consist of the sudden appearance of vitreous floaters or light flashes. It has been reported that among patients older than 50 years of age, the symptom of suddenly appearing floaters is known to be caused by posterior vitreous detachment in 95% of cases [27].

Patients with this complaint all should be thoroughly and conscientiously examined with indirect ophthalmoscopy and simultaneous scleral indentation in both eyes, to search for any new tractional retinal tear or tears that may be present. If such are discovered they should be promptly treated by surrounding them with either laser photocoagulation or cryotherapy. It has been found in several clinical series [14, 28–31] and in an autopsy series by Foos [32] that about 15% of eyes that have had a vitreous detachment also have a tractional retinal tear or tears. It has been reported that around 28% of these will progress to a retinal detachment before the patient first consults an ophthalmologist [33].

If the remaining 72% of eyes with fresh retinal tears are not promptly discovered and treated, about one-third of this number will progress to a retinal detachment either very soon or within 2–3 months. Among eyes discovered with fresh tractional retinal tears but which have not yet led to retinal detachment, it has been well established that about 35% will lead to retinal detachment [34–36].

Therefore, prompt examination of patients with suggestive symptoms of vitreous detachment, followed by prompt treatment of any new tractional retinal tears, is mandatory and will provide a high probability of preventing further progress to a retinal detachment, which is a much more serious event. Altogether these account for approximately 95% of all retinal detachments. If all fresh retinal tears resulting from posterior vitreous detachment were discovered at the time when no retinal detachment was yet present, and were successfully treated at that time, then approximately 44% of retinal detachment in general could be prevented (Table 2.4). We must remember that about two-thirds of the eyes with such tears would never progress to detachment even without treatment. Herein lies a very great opportunity for the successful prevention of this historic and continuing scourge of vision.

It may be thought that eyes that undergo a sudden posterior vitreous detachment may have a still higher risk if they contain pre-existing visible predisposing lesions related to retinal detachment. However, in a large prospective study of such eyes [14] it was

Table 2.4. Fate of new retinal tears resulting from posterior vitreous detachment

Progressing promptly to retinal detachment (before consulting ophthalmologist)	28%
Expected to progress to detachment (without treatment) = 72/3	24%
Total progressing to retinal detachment (without treatment)	52%
Proportion of retinal detachments prevented (in general)	44%

found that eyes with pre-existing retinal breaks do not have any increased risk of retinal detachment following PVD. The same was true of eyes with pre-existing senile retinoschisis (N.E. Byer, unpublished observations). In the group of eyes with pre-existing lattice degeneration the onset of sudden PVD did lead to new retinal tears in 24% (N.E. Byer, unpublished observations). In 76% of the eyes with lattice degeneration, the occurrence of a PVD did not produce any complication of any kind (N.E. Byer, unpublished observations). However, in 50% of the lattice-eyes the new tears appeared in "normal"-appearing retinal areas and, thus, could not have been pretreated (using the "prophylactic" method) because they would not have been detected.

In summary, the conscientious examination of patients with recent symptoms of posterior vitreous detachment, followed by discovery and treatment of new retinal tears, provides the capability of preventing around 44% of rhegmatogenous retinal detachments. The older practice of "prophylactically" treating eyes with predisposing retinal lesions has led only to a disappointing and questionable clinical benefit. That procedure should be officially discarded, and the above much-preferred method should be recognized as the proper standard of care. This then is the obvious and available answer to the question of "What to DO" to prevent retinal detachment.

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Encircling Operation with Drainage for Primary Retinal Detachment

Hermann D. Schubert

Encircling circumferential buckles and drainage, also known as "scleral buckling", were introduced by Arruga and Schepens [1, 2] in the 1950s. Encircling traces its roots to circumferential dissection [3], barrier diathermy [4] and the buckle as practiced by Jess [5] and Custodis [6]. Drainage can be traced back to repeated scleral punctures to flatten retinal elevations (ponction sclerale) [7] and Jules Gonin's ignipuncture technique [8]. This chapter will review the reasons why eyes were originally encircled, why the procedure works in a majority of cases, and why eyes are still being encircled and drained today, despite the procedure's inherent morbidity.

Origins of Encircling: Arruga and Schepens

Arruga devised a simple procedure using a nylon, silk or supramid suture to encircle the equator of the eye (Fig. 3.1). Breaks were either diathermized according to Gonin's principle or isolated by a barrier: "Je diathermise la region des dechirures, ou aux endroits qu'il faut isoler par un barrage" [1].

Arruga's operation consisted of a treatment of breaks, creation of barriers, and volume reduction. Fluid was drained from and air was injected into the eye to replace lost volume. Tying a suture at the equator (14 mm posterior to the limbus) both reduced the volume of the ocular cavity, relieving vitreous traction, and protected the posterior segment from the torn anterior segment, at the price

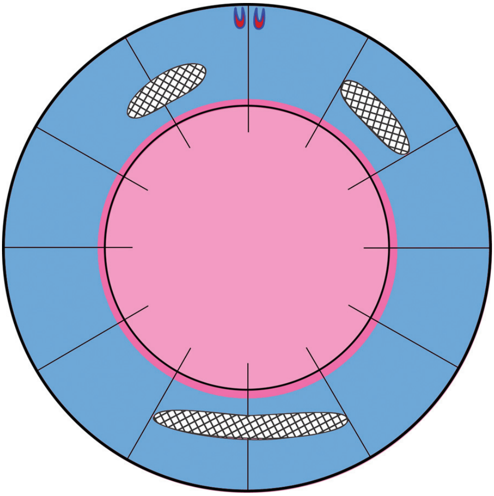

Fig. 3.1. An Arruga suture was placed 14 mm posterior to the limbus to protect the posterior segment from the "porous" anterior retina

of constriction. Constriction could lead to intrusion of the suture into the eye and narrowing of the lid fissure [9], but more often it would lead to ocular ischemic symptoms: lid edema, chemosis, uveitis and ocular hypotension, also described as the "string syndrome" [10].

At about the same time, Schepens recognized the imperfect location of an equatorial circling suture, which walled off anterior breaks without really buckling or closing them. He wrote that "Such a barrage forms a dyke, which limits the detachment to the area surrounding the untreated retinal breaks and protects the portion of the retina which has potential usefulness" [2]. The location (latitude) of the circling polyethylene tube was determined by the posterior edge of the most posterior retinal break. Ideally, all breaks of similar latitude would come to lie on the anterior slope or the crest itself, which would follow as closely as possible "the great circle of the eyeball" [2].

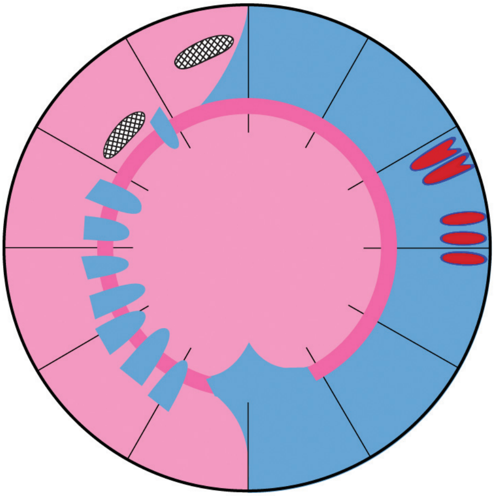

Fig. 3.2. A 32-year-old myopic woman whose eye was constricted with a 55-mm overlapping band. The fundus drawing shows the "purse-string sign", meridional folds and the barrier function which is incomplete inferiorly of the 2.5-mm band. The eye was uncomfortable with signs of iritis as part of the "string syndrome"

Breaks posterior to the crest would lead to failure, whereas those too far anterior to be buckled could be walled off by diathermy barriers. After drainage, the encircling band was shortened up to 25–30 mm in severe cases of massive vitreous retraction. Since the retinal circumference at the equator measures 72 mm in the emmetrope, such reduction was 40%, complicated by meridional folds or fishmouthing of the horseshoe tear(s) and subsequent redundant folds across the crest of the buckle (Fig. 3.2).

The 1957 encircling operation closed breaks in the chosen latitude and walled off anterior breaks, but it did not reliably support the anterior horns of horseshoe tears [11,12]. Anterior buckling was improved by the addition of myriad shapes of wider explants, including "accessories", "radial wedges" and "meridionals," which are still available commercially today [13].

How Encircling Works

Similar to a circumferential buckle, encircling closes breaks by corking them functionally at the crest, interrupting the conduit of fluid through the hole. The constriction permanently reduces traction on the break and volume reduction concentrates the vitreous mass, both facilitating apposition of the retina and plugging of the tear. This may be particularly beneficial in small undetected full thickness holes, which remain relaxed, supported and corked and, therefore, may never become functional. As Gonin said, "La masse pulpaire du vitre, formant elle-meme bouchon au devant de l'ouverture, favorise cette obliteration" [7].

With and without intraocular injection of gas the inferior retina has been prone to break formation. In 1921, Gonin pointed to the traction-reducing effect of the weight of the vitreous mass on the inferior retina. He felt, however, that the inferior vitreous attachment was firmer and of larger surface, "En revanche, par suite du contact plus direct et plus durable qui existe entre la pulpe du vitre et la retine dans les parties declives, les adherences ont chances d'y etre plus intimes et plus etendues" [7].

Buckling of the vitreous base, as in encircling [14], might provide protection against increased vitreous traction, particularly inferior. Most vitreous proliferation starts inferiorly and is stimulated by trauma or vitreous manipulation. Gas bubbles, depending on buoyancy, may contribute to inferior traction directly. Encircling protects the vulnerable vitreous base, as seen by the paucity of retinal breaks after encircling as opposed to pneumatic retinopexy [15], and the barrier effect of prophylactic laser treatments, which include the inferior periphery [16].

Complications of Encircling

Complications of encircling include surgery in all quadrants in all cases, increased myopia, strabismus, internal erosion, the string and

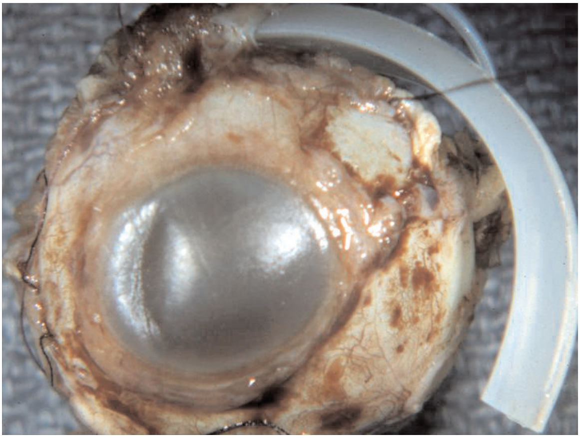

Fig. 3.3. Pathological specimen of an enucleated eye with a *large buckle* which had caused motility problems

purse-string syndromes as well as short- and long-term effects of choroidal ischemia and reduced pulse amplitude [17, 18].

Some of these events can be controlled with careful technique. Conjunctival scarring and chronic dry eye can be reduced by meticulous attention to Tenon's capsule and careful dual layer closure. (It is unfortunate that closure is at the end of a challenging and tiring operation and is often delegated without much supervision). Strabismus can be reduced by careful handling of orbital tissues and muscle retraction and by choosing small instead of large buckles [19–21] (Fig. 3.3).

Meticulous restoring of the anatomy will limit scarring. Motility can be improved by postoperative ocular exercise. Erosion and string syndrome can be avoided by limiting constriction to 10% [22] (Fig. 3.4). Overzealous constriction ("high and dry") can be corrected later by cutting the band. More difficult post-surgical judgements are presented by insidious choroidal ischemia and reduced pulse amplitude [17, 18]. Typically, the retina is attached and the vision is good yet there may be mild chronic irritation/

Fig. 3.4. Pathological specimen of an enucleated eye that had a *tight encircling buckle* which had covered the vortex vein ampullas. The retina was attached at the price of constriction and ischemia

inflammation and macular pigmentary changes that could also be ascribed to the original detachment or aging. It is difficult to propose to a patient that cutting the band at a small risk of redetachment might prevent future macular changes and ill-defined degeneration; however, the intervention might prove more effective than daily antioxidants.

How Drainage Works

Although fluid drainage was part of Gonin's ignipuncture technique, it had been performed without attention to retinal breaks and accordingly with predictably poor results. Rosengren, who injected air intravitreally, also drained [23]. Arruga and Schepens both drained subretinal fluid to bring the neuroepithelia into apposition and to make space for the volume reduction that encircling entailed. Drainage also shortened recovery time, which both relieved the unease of the surgeon and shortened hospital stays from weeks and months (Treatment of Samelsohn, [7]).

Schepens reserved bed rest for macula-on retinal detachments. For all other detachments, subretinal fluid was desirable, since it made volume reduction more effective and safer: "In all other cases, the patients are encouraged to be up and about, in order to keep the retina detached prior to surgery, because the scleral buckling operation, which necessarily decreases the volume of the eye, requires the loss of ample subretinal fluid at the time of operation" [2]. The amount of fluid to be removed from the eye was investigated by Thompson and Michels. The volume displacement of a 2.5-mm-wide band was measured to be 0.5 ml; with explants, the displaced volume could be close to 2 ml or up to 45% of the vitreous cavity [24].

Complications of Drainage

Complications of drainage include hemorrhage, choroidal detachment, retinal incarceration, iatrogenic retinal holes, and infection. Cibis wrote about the uncertain nature of a release of subretinal fluid: "This is perhaps the most dangerous step in any of the retinal detachment procedures presently employed, except where Custodis' technique is used" [25].

Intraocular bleeding (major retinal, subretinal, or vitreal) was seen in 14.4% of drained versus 3.3% of undrained cases [26]. Choroidal detachment occurred in 8.6% of drained versus 1.6% of undrained cases. Both bleeding and choroidal detachment reduced the probability of reattachment and good postoperative vision in this population-based study [26]. Choroidal edema was found more frequently in older patients after drainage, hypotony, encircling, larger buckles, more extensive cryopexy and more complete vortex vein obstruction [19].

Kreissig, who drained 98.7% of cases from 1966 to 1969, reported intraocular hemorrhage (smallest or larger) in 15.6% [28]. In 1975, Blagojevic, who drained 96% of cases, found intraocular hemorrhages in 16% and retinal incarceration in 1% [29]. Huebner, who drained 89% of cases, found intraocular hemorrhages in 6.9% and retinal incarceration in 0.7% [30]. Also in 1975, Spalter reported iatrogenic retinal holes related to drainage that had occurred in 2.3–14.8%, often accompanied by vitreous loss, depending on the technique used [31].

Improvements in the technique of drainage included transillumination of the choroid to identify large vessels, diathermy [32], puncturing away from vortices and long posterior ciliary vessels [29], using the microscope [33], using traction [31], or incomplete drainage [34].

All of the reports on drainage and its complications are retrospective. It is hard to imagine a detailed report about the exact submacular distribution of blood in the operative note. Yet, as Cibis wryly remarked, "As you all know, surgeons, as a rule, do not report their complications and mistakes unless they are related to a technique devised by another surgeon" [25]. Nevertheless, reports of failures exist, relating failure to complications of drainage in a majority of cases [35]. Underreporting of less than a "major hemorrhage" is likely. Blagojevic, who noted intraocular hemorrhages in 16% wrote: "It is important to stress that [the intraocular hemorrhages] were never widespread, and that they did not unfavorably affect the results of the operation. Hemophthalmus and choroidal hematoma were not noticed" [29]. There have been many modifications of the drainage technique [27–34], attesting to the difficulty of producing a bloodless perforating injury in a highly perfused, inflamed and hypotonous vascular layer. Added risks over the past seven decades have been increasing patient age and widespread use of anticoagulants. Possibly, poor visual acuity found after "scleral buckling" might be related to underreported complications of drainage and layers of barely visible subretinal blood under the fovea (Fig. 3.5).

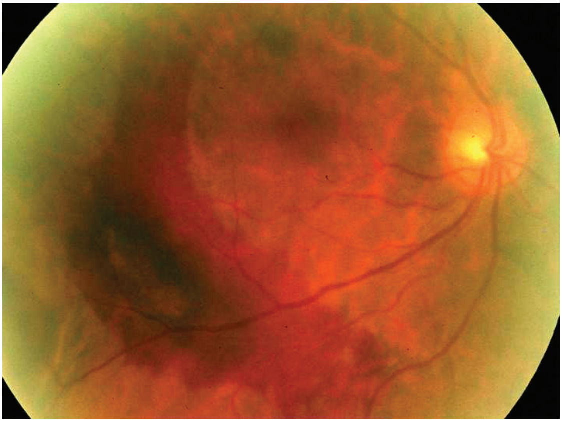

Fig. 3.5. Subretinal blood after drainage. It is parafoveal, but vision remained poor

Are Encircling and Drainage Still Popular Methods?

In light of the above tales of both success and morbidity, are encircling and drainage still done? The short answer is that encircling with drainage, as opposed to minimal segmental buckling without drainage [36], requires less-accurate meridional localization of all breaks, is subsequently somewhat easier to do, and works at the short-term risk of hemorrhage and long-term risk of choroidal ischemia.

In more recent (1982–2002) clinical series on scleral buckling [15, 26, 37, 38], encircling was practiced in 43–100% (average 74%) and was combined with drainage in 72–85% (average 78%) of total cases. Gas was injected in 26–32% in two series; this procedure is also known as "pneumatic buckle" [15, 37]. Primary success ranged from 78% to 96% (average 85%). Obstacles to success were aphakia/pseudophakia, whereas the main benefit of encircling relative to alternate procedures was found to be the low incidence of secondary tears (1.3% versus 18–20%) [15].

It is of note that two of the series [15, 37] compared scleral buckling (78–100% encircling and 72–85% drainage) to pneumatic retinopexy. Scleral buckling was therefore used synonymously with encircling and drainage in the recent literature and we can assume that it represents the standard of care.

Encircling at Wills Eye Hospital in 1985

To test this hypothesis, that encircling and drainage are still the primary procedure, the author reviewed 100 consecutive scleral buckling procedures done at Wills Eye Hospital from 1985 to 1986. Eleven members of the retina service encircled primary detachments in 83% and drained in 73% of cases, consistent with the literature.

Air or gas was injected in 6%. The extent of the detachment was one quadrant in 10%, two quadrants in 52%, three quadrants in 21% and four quadrants in 17%. The average area of detachment was 2.9 quadrants.

The preferred buckling procedure consisted of a 3-mm encircling band used in 83%, combined with a 7-mm explant which was used in 73%. The explant covered 2.3 quadrants on average so that in 49% of all cases it covered the entire extent of the detachment (Fig. 3.6). The primary success rate was around 90%. The author had no follow-up after discharge from the hospital, except for re-admissions.

It is easy to see why this skillfully executed procedure had a high success rate. Careful preoperative study was mandatory as was a detailed retinal drawing. (Encircling and drainage did not mean that the study of the retina was optional). Patients were admitted the day before surgery, were studied in the evening and stayed overnight to help flatten the detachment. During surgery, all breaks were carefully marked on sclera to ensure their placement on the crest or anterior slope of the buckle. Cryopexy was applied to breaks, lattice and suspicious retinal lesions. Since the majority of

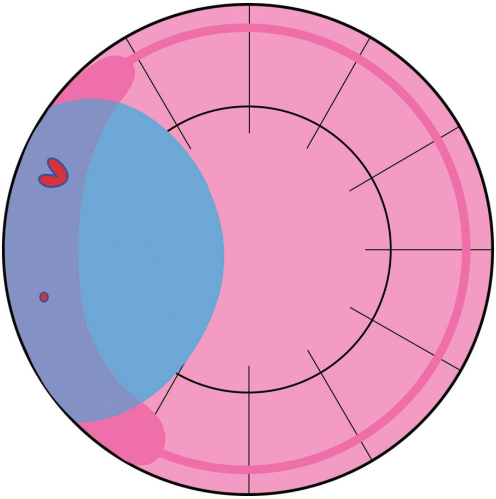

Fig. 3.6. Example of routine encircling and drainage: The eye was buckled with a 7-mm explant for the entire extent of the detachment. Drainage was made near a rectus muscle in the bed of the buckle. A 2.5-mm band was used to encircle the eye to barricade undetected breaks

breaks were located at a latitude 13–14 mm posterior to the limbus, detected, undetected and anticipated future breaks would be covered.

How Buckling Was Modified in One Practice

The author reviewed his last 100 scleral buckling procedures comprising his personal experience at the Harkness Eye Institute between 2000 and 2003. Encircling was done in 17%, drainage in 6%, and air was injected in 11%. Gas was not used. The detachments extended one quadrant in 14%, two quadrants in 45%, three quadrants in 35% and four quadrants in 6%. The detachments averaged 2.3 quadrants as opposed to 2.9 quadrants at Wills Eye Hospital.

Double patching and bed rest were encouraged whenever possible. After localization of all breaks and cryopexy, 5-mm sponges were applied in 82%. They were placed radially in 49% and circumferentially in 33%. The primary success rate was 87%.

Reasons for Modification

As indicated above, the success rate depends on case selection, length of follow-up, whose cases they are, who evaluates them, etc. The impetus for change in the latter series was the unavoidable morbidity associated with encircling and drainage. In order to make sure that the overall success rate corresponded to the published norm of 80–90%, modifications occurred gradually – first by tying the band loosely, then by omitting it. Modifications were also made by shortening the circumferential 7-mm explant and finally by just buckling the breaks, preferably in a radial orientation. Fewer and fewer cases were drained, sometimes at the cost of sleep.

This experience somewhat parallels the trend described by Lincoff, who drained 48% of cases in 1963 and only 13% by 1971 [39], or by Kreissig who drained almost all cases in 1966, 6% of cases in 1972 [40] and none in 1992 [36]. The reasons for drainage were (1) giant tears, (2) severe preretinal retraction, (3) uncertain localization of the break, (4) defective choroid, (5) thin sclera, or (6) glaucoma [39]. Reasons 1–3 might be managed by vitrectomy techniques today including encircling with the ubiquitous 3.5-mm band, which reduces indications for drainage.

Are Encircling and Drainage Still Worth Doing?

As every detachment surgeon knows, there are detachments of good and of poor prognosis. Good prognostic signs include: fewer breaks, less extensive area of detachment, shallow detachments and

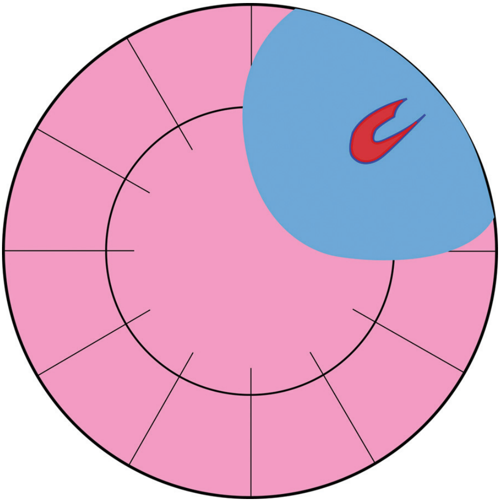

Fig. 3.7. A detachment with a good prognosis. A one-quadrant detachment, one break, in a 50-year-old male patient, flattened with bed rest. A radial 5-mm sponge was placed, followed by laser

phakic status (Fig. 3.7). Indicators of poor prognosis include: many breaks, undetectable breaks, a large area of detachment, bullous detachment, aphakic/pseudophakic status and proliferations of vitreous and retina (Fig. 3.8). Not surprisingly, these indicators are similar in the literature on both buckling and pneumatic retinopexy [16].

Minimal procedures are appropriate to repair more favorable cases, whereas procedures associated with higher morbidity are reserved for the complex case. Schepens corroborated this finding. "The circling element was at first used in cases with an unfavorable prognosis. As experience with this procedure increased it was used on more and more favorable cases and it was found to be the most dependable operation" [2]. This misconception, that if it is good for complicated cases it is even better for uncomplicated ones, has proved to be a common reasoning in clinical practice, as observed by Lincoff and Kreissig [41].

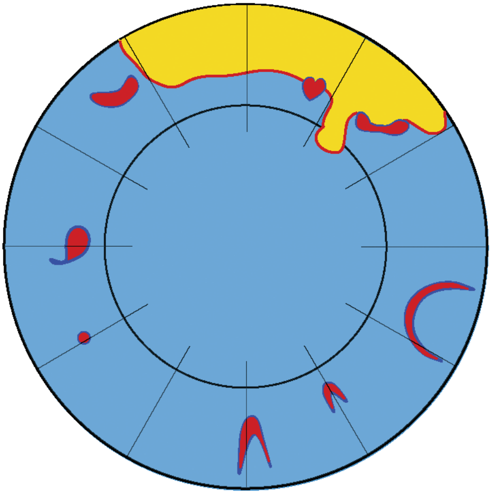

Fig. 3.8. A detachment with a poor prognosis in a 42-year old male patient. There were eight breaks. It was a reoperation with PVR stage B, unresponsive to bed rest. Five segmental buckles were placed. The retina attached without drainage. After 3 months the retina redetached due to PVR. This may represent the limit of the segmental buckling technique

Encircling and drainage may still be of value in highly bullous detachments not responding to bed rest, many breaks of similar latitude, anterior vitreoretinopathy, need for a higher and more permanent buckle and thin sclera interfering with suturing. The author prefers encircling for most revisions of failed segmental buckles. The reasons are psychological and practical: the minimal procedure has failed and the revision includes the preparation for possible vitreous surgery. The band is in place, but may not be tied.

Conclusion

Whereas modern examination techniques facilitate localization of breaks and allow for precise treatment of the holes, drainage and encircling continue to be popular and are used by a majority of surgeons. Careful preoperative examination including a detailed fundus drawing was advocated by Schepens and should still be done, irrespective of the surgical method. Examination is time consuming in the age of managed care and even the best effort cannot always identify all breaks. For the buckling procedure to be successful, all breaks have to be identified and closed, encircled or not.

Encircling and drainage were successful in 78–96% and have become synonymous with scleral buckling [15, 37]. Since the 1950s, at least two generations of surgeons have been well trained in this procedure. It is "dependable" and incorporates the barrier concept [2]. Intraoperative localization as to latitude is critical, but meridional localization may be less precise compared with minimal radial buckling. The vitreous base is ring-like; supporting it treats the hidden break and the anticipated traction. Broad buckles support anterior PVR and circumferential retinotomies [42]. This "ring" concept is behind prophylactic buckling and laser circling for 360 degrees, as they are meant to barrage and reduce the incidence of secondary breaks in alternate techniques [14, 16]. Most encircling is reversible: a band can be cut in a timely fashion without re-detachment or permanent damage from ischemia.

Can the surgeon sleep better after the retina has been drained flat? It depends: a non-drainage procedure increases the chance of primary failure, but the eye will survive the attempt almost intact. By draining, the retina may be attached on the table, yet morbidity (blood under the macula etc.) may forever preclude visual recovery. Who could sleep well after the latter? From a pathologist's viewpoint, drainage will always be a penetrating injury to a vascular tissue in an inflammatory and hypotonous setting. The data reporting intraocular hemorrhage attest to this simple fact that cannot be changed by even the most sophisticated technique. The fear of anatomic failure (first operation success or lack thereof) apparent to both physician and patient has helped the propagation of techniques that flatten the retina under the surgeon's eye, like external drainage or internal drainage during vitrectomy. Both procedures share the complications of penetrating ocular injury.

After careful examination, a skillfully executed encircling and drainage operation has a high rate of success. However, morbidity leads to a gradual change in the author's practice. Encircling and drainage are not necessary conditions for a high rate of first operation success after scleral buckling; in fact, one can be equally successful employing less-morbid procedures. An editorial concluded that "accurate localization of all retinal holes and precise placing of the buckle are of course essential, and confidence in the success of the procedure is necessary to outweigh a fear of failure induced in the surgeon by the presence of fluid under the retina at the end of the operation. The temptation to drain and 'make sure' must be resisted. Yielding may well court complications" [43].

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Pneumatic Retinopexy for Primary Retinal Detachment

Eric R. Holz, William F. Mieler

Introduction

Pneumatic retinopexy (PR) is a minimally invasive surgical technique utilized for the repair of rhegmatogenous retinal detachment (RRD). It is composed of intravitreal gas injection, either cryopexy or laser, and postoperative patient positioning. Historically, the first report of the use of intraocular gas injection for the treatment of RRD appeared in 1911 [1]. Rosengren, in 1938, reported the first large series of patients treated with intraocular air injection, drainage of subretinal fluid (SRF), and diathermy [2]. The modern PR technique was born in 1985 with simultaneous reports by Hilton and Grizzard in the United States [3] and Dominguez in Spain [4, 5].

The PR procedure appears to be gaining in popularity, although there is considerable variation in its use based on geography and practitioner's years in practice. Surveys of American vitreoretinal specialists in 1990 and 1997 revealed an increase in use from 38% to 55% for a given "ideal" clinical scenario. There was significant variation in the choice of surgical technique based on surgeon age. Those in practice less than 10 years chose PR 65% of the time compared with 35% of those in practice 20 years or more. Within the United States, there was regional variation with 74% of survey respondents in western states choosing PR compared with 43% in north central states [6].

The rise in the popularity of PR may be due to the perceived benefits to the patient, the attending physician, and society as a whole. Well-informed patients typically prefer PR because of its minimally invasive nature. There is little pain, more rapid return of vision, and fewer postoperative complications, resulting in a more expedient return to daily activities. For the surgeon, the procedure is quick, technically easy, and performed in the outpatient or office setting. These advantages, combined with the procedure's low cost, have led to increased interest and usage of PR for the treatment of primary RRD.

Technique

Pneumatic retinopexy consists of several key elements, including proper preoperative patient and case selection, gas injection, laser or cryopexy, and postoperative positioning.

Patient Selection

The use of PR demands a high degree of patient understanding and compliance in order to succeed. The most frequent cause of failed closure of the primary break(s) is inadequate tamponade due to patient non-compliance. As a result, the patient must be able to understand the vital role of bubble positioning during the early postoperative course. The surgeon should take extra care educating the patient preoperatively about the desired head position. Taking the patient's head in his/her hands and turning or tilting it to the proper orientation is frequently helpful. Involving accompanying family or friends in the discussion may reinforce the message. Physically, the patient must be able to comply. Those with arthritis, neck or back problems, or other physical constraints are less desirable candidates for PR. In general, a young, bright, highly motivated individual is the best candidate for the PR technique.

Case Selection

Proper case selection is critical to success with PR. The "ideal" scenario involves an acute, phakic retinal detachment due to a single break or small cluster of breaks located in the superior 8 clock hours of the fundus. Careful preoperative examination is exceedingly important when considering PR. Clear ocular media are essential to allow visualization of all breaks. Sector cataract, vitreous hemorrhage, and pseudophakic lens capsular opacification are relative contraindications. In general, pseudophakic and aphakic detachments are more prone to multiple small breaks than phakic cases. However, if the view to peripheral retina affords a view sufficient to disclose all the breaks, these detachments can be managed with PR. A single break is most easily covered with bubble tamponade. If multiple, the breaks must be close enough together to be covered by a single bubble. Breaks greater than 90–120° apart require large volume injections and, as a result, are relative contraindications. Retinal tears located in the superior 8 clock hours are easier to treat because gas bubbles float in the fluid vitreous. Although retinal tears in attached retina located inferiorly are easily managed with barricade laser, breaks in detached retina in the inferior 4 clock hours present a relative contraindication for PR (see below – New possibilities).

There are several other contraindications to PR. Required patient air travel while the bubble is in place is an absolute contraindication. There is no relief of vitreoretinal traction with PR; the adhesion formed must be stronger than the tractional forces generated to achieve long-term success. As a result, patients with severe traction due to proliferative vitreoretinopathy (PVR) are not good candidates. Subretinal fluid is removed by the pigment epithelial pump. This process is much more efficient with the liquid SRF of acute detachments than with the viscid proteinaceous fluid encountered with chronic detachments. Pneumatic retinopexy can be successfully utilized with the latter, but there may be loculated pockets of chronic SRF that persist for months due to delayed resorption. The combination of glaucoma with retinal detachment leads to several considerations with respect to PR. Patients with a functioning bleb or tube shunt device in place may be better managed by PR than scleral buckle (SB). Although an expanding gas bubble has the potential to dramatically raise the intraocular pressure (IOP), bubble expansion typically occurs simultaneously with resorption of SRF. The resolution of SRF provides potential space for bubble expansion without perturbations in the IOP. Only detachments with scant SRF or chronic, thick SRF are more prone to IOP problems and, as a result, are relative contraindications to PR in patients with coexisting glaucoma.

Gas Selection

Intraocular gas works by temporarily closing retinal breaks via the surface tension properties of the bubble meniscus. Blocking the movement of liquid vitreous into the subretinal space allows the retinal pigment epithelium to actively pump fluid from the subretinal space and flatten the detachment. Once the neurosensory retina is in apposition to the pigment epithelial layer, the adhesive properties of cryopexy or laser retinopexy permanently close the break(s). The most commonly utilized gases are air, sulfur hexafluoride (SF_6), and perfluoropropane (C_3F_8). Choice of gas is based upon volume issues, arc length of contact/bubble size requirements, and bubble duration (Table 4.1) [7]. The tamponade must last until the laser or cryopexy adhesion is strong enough to resist reopening – generally 3–5 days for laser and 5–7 days for cryopexy. Air is non-expansile and quickly disappears from the eye. Sulfur hexafluoride and C_3F_8 are expansile and have longer half-lives. In general, a 1-ml final bubble size tamponades a 120° arc length, which is sufficient for most cases of PR (Table 4.2) [8]. There is, however, considerable variation based on the axial length/ size of the globe, so that larger bubbles are required in myopic individuals to achieve the desired arc length of contact.

Table 4.1. Gas characteristics (from [7])

	Expansion	Half-life (days)	Isoexpansile concentration	Standard volume (pure gas)
Air	0	1	100%	0.5–1.0 ml
SF_6	2.0–2.5×	2.5	18%	0.5 ml
C_3F_8	4×	4	14%	0.3 ml

Table 4.2. Bubble size/tamponade arc. Arc varies with axial length/size of globe (from [8])

Final bubble size	Arc of contact
0.30 ml	90°
1.0 ml	120°
3.0 ml	180°

The volume of the initial injection is a key consideration in gas selection. Intravitreal injections of 0.1–0.2 ml usually result in modest IOP rises, but increasing the initial volume beyond this point dramatically increases pressure. Paracentesis provides potential space within the globe, but is usually limited to 0.1–0.2 ml. As a result of these considerations, the authors routinely use 0.25 ml of pure (100%) C_3F_8 gas, which provides a small initial injected volume and a large final volume (~1 ml) sufficient to tamponade most breaks.

Technique

Pneumatic retinopexy is either performed in one or two steps, depending on whether cryopexy or laser is utilized to form the chorioretinal adhesion (Tables 4.3, 4.4). Anesthesia may be applied

Table 4.3. Required materials

Anesthetic of choice
Povidone–iodine 5% solution
Eyelid speculum and caliper
Several sterile cotton-tip applicators
1-ml syringe/30-gauge needle – plunger removed (if paracentesis)
Gas cylinder/tubing
Millipore filter
1-ml or 3-ml syringe/30-gauge needle
Cryotherapy unit or laser
Antibiotic/steroid combination ointment
Patch materials

Table 4.4. Pneumatic retinopexy technique steps

Apply anesthetic of choice
Prepare eye – povidone–iodine 5% – 5 min ×2
Prepare chosen gas
Place eyelid speculum
Perform cryopexy (one-step procedure)
Paracentecis (surgeon's choice)
Position patient, head
Caliper measurement – 4 mm
Inject gas bubble/location
Inspect gas location, central retinal artery perfusion
Check intraocular pressure until normalizes
Patch with arrow drawn
Laser (next day, if two-step procedure)

by topical, subconjunctival, peribulbar, or retrobulbar routes. A retrobulbar or parabulbar injection is given when cryopexy is planned, while topical or subconjunctival administration is sufficient for gas injection alone. The globe, eyelids, and periocular skin are prepared with a 5% povidone–iodine solution applied twice at 5-min intervals. Some surgeons choose to add a topical antibiotic solution; however, these need to be started 24–48 h prior to the procedure with frequent use to substantially affect the ocular flora, limiting their usefulness as a true prophylactic method in this setting. A wire-lid speculum is used to open the lids, avert the lashes from the field, and protect the lid margin from cryopexy damage. If the patient is to undergo a one-step procedure, then cryopexy is performed prior to gas injection, as small breaks may be difficult to visualize following gas injection. Cryopexy is the preferred method in cases where media opacities limit the view, when the break(s) are located in the far periphery, or when there is underlying pigment epithelial atrophy. Laser, via a two-step method, is preferred with bullous superior detachments with large retinal breaks, when breaks occur over a previously placed buckle element, and with posteriorly located tears. Some surgeons feel that there is a lower incidence of PVR with laser retinopexy compared with cryopexy. Laser can be difficult to perform through or around the gas bubble and will not provide adequate adhesion if there is still a small amount of fluid present near the tear site. Small breaks may be difficult to find with the laser once the retina is reattached. Laser might form a chorioretinal adhesion faster than cryopexy, which decreases the critical duration of required post-operation positioning. Multiple rows of confluent laser are placed around each tear with careful attention to carry the treatment anterior to the ora serrata. It should be noted that the two methods are not mutually exclusive, and many instances are best managed by a combination of both modalities.

Preparation of the chosen gas is performed by withdrawing gas from a cylinder via a valve system through a Millipore filter into a 1-ml or 3-ml syringe. The valve, tubing, filter, and syringe are flushed with gas once, and the process is repeated to eliminate room air from the system. High pressures may damage Millipore filters, so care must be taken to maintain lower pressures during gas filtration. The filter is replaced with a 30-gauge needle, and excess gas is pushed out of the syringe until the desired amount for injection remains behind.

Paracentesis of the anterior chamber is a controversial step in the procedure. Some surgeons routinely soften all eyes prior to injection, while some perform the step only rarely. Others perform paracentesis after the gas injection as required by the IOP. Paracentesis is less important with one-step procedures where the scleral depression associated with cryopexy softens the globe and in cases where smaller volumes of expansile gas are utilized. Paracentesis is most often required in two-step (laser) cases and when injecting large gas volumes. The step is performed by entering the anterior chamber with a 30-gauge needle affixed to a 1-ml syringe without the plunger. Aqueous humor is allowed to passively egress until the anterior chamber shallows. A sterile cotton tip applicator is rolled onto the needle track as the needle is withdrawn to avoid additional fluid egress. Care is given to avoid needle tip-lens touch. Paracentesis is contraindicated in aphakic and pseudophakic patients with vitreous prolapse into the anterior chamber.

Gas injection is the most important component step of PR, and many postoperative complications can be avoided with proper technique. The surgeon utilizes the indirect ophthalmoscope for lighting, visualization of needle tip, and later to assess gas location and patency of the central retinal artery. The patient is placed in a recumbent position with the head tilted 45° away from the operative eye. This places the temporal pars plana as the highest point on the globe. The injection is given 4 mm posterior to the limbus, usually in the temporal quadrant, unless the retina is bullously detached in the area. The needle tip is advanced into the mid-vitreous cavity, under direct visualization with the indirect ophthalmoscope to penetrate the anterior hyaloid face. Then the needle is withdrawn until just the tip is visible, 2–3 mm through the pars plana epithelium. Gas is injected in a brisk but controlled manner. Following gas injection, the head is carefully rotated to a neutral position in order to move gas away from the injection site and avoid egress of gas out the needle track. A sterile cotton tip applicator is rolled over the track as the needle is removed to minimize gas reflux. Following gas injection, the bubble size and position are assessed, and central retinal artery perfusion is assured with indirect ophthalmoscopy.

IOP rises abruptly in most patients who receive greater than 0.2 ml gas. The IOP is checked immediately following gas placement. Frequently, pressure measurements fall in the 50–70 mmHg range. If the patient has a normal aqueous outflow mechanism, he or she can be monitored with serial tonometry every 10–15 min, which frequently demonstrates a return to more normal pressures over 15–30 min. Paracentesis, as noted above, may be performed before or after gas injection (or both) to normalize IOP. The pressure should be near normal and the central retinal artery perfused prior to the patient's departure.

Postoperatively, an antibiotic/steroid combination ointment is placed in the eye, and a patch is applied. An arrow is drawn on the patch, such that the arrow points straight at the ceiling when the patient is properly positioned (break in uppermost position of the globe). The patient and caregiver are reminded of the required position with special emphasis on the need for compliance, especially at night while asleep. The patient returns for follow-up on the first postoperative day. The SRF is usually substantially improved or entirely resolved. The gas bubble size and location are assessed, and the IOP is measured. Laser may be performed as part of a staged procedure (see above). For patients with extensive cryopexy, antibiotic and steroid drops may be prescribed for a few days. The importance of proper position is stressed yet again. In cases where there is little or no change in the SRF, patient compliance is reassessed, and an exhaustive exam for new or missed breaks is undertaken. In the typical scenario where the fluid is substantially better, the patient is re-examined on the third to fifth postoperative day.

Complications: Prevention and Management

Intraoperative

There are limited complications associated with the use of PR. The most common set of problems arise from difficulties with the gas bubble itself, particularly migration into unintended potential spaces. Subconjunctival gas is the most common location, being reported in 0–10% of cases (Table 4.5) [3, 9–11]. Gas has also been reported in the subretinal space (0–4%) [12–15], anterior to the anterior hyaloid (0–9%) [11, 13, 14], in the suprachoroidal space (0–5%) [13–15], and exterior to pars plana epithelium (0–1%) [9]. Following injection, the gas inside the eye may form multiple small "fish egg" bubbles rather than a single large one. Fish eggs provide inadequate tamponade, as they do not occlude breaks with the same efficiency as a large smooth meniscus. This same feature also makes them more likely to migrate into the subretinal space. Multiple small bubble formation can usually be avoided through proper injection technique (see above). When this does occur, the eye may be forcefully tapped or "thumped" with the surgeon's finger, which can lead to coalescence (a technique that has been described,

Table 4.5. Reported intraoperative complications

Subconjunctival hemorrhage [3]	Up to 60%
Subconjunctival gas [3, 9–11]	0–10%
Anterior hyaloid gas [11, 13, 14]	0–9.7%
Vitreous hemorrhage [3, 9, 13, 15]	0–5%
Choroidal detachment [13–15]	0–5%
Subretinal gas [12–15]	0–4%
Vitreous incarceration [9, 10, 12, 13]	0–3.6%
Sub pars plana gas [9]	0–1%
Subretinal hemorrhage [13]	0–1%
Hyphema [13, 14]	0–1%
Lens touch [13]	0–1%

though perhaps not employed by all). If this maneuver fails, the patient should be positioned face down for 6–12 h in order to prevent subretinal migration. During this time period, fish eggs inevitably unite to form the desired, effective single large bubble. Migration of bubbles, especially with expansile gas, into the subretinal space is a substantial complication. This event can be avoided by visualizing the needle within the vitreous cavity prior to injection, achieving a single bubble rather than fish eggs, and by avoiding case selection involving large tears with severe traction. Once gas enters the subretinal space, it may be managed by maneuvering the patient's head and eye in such a way that it rolls the bubble back through the tear into the vitreous cavity. This is often aided by simultaneous scleral depression. These maneuvers are often unsuccessful, and vitrectomy surgery is necessary for removal. During vitrectomy, the bubble will displace the detached retina anteriorly toward the lens – making infusion line placement, sclerotomy incisions, and instrument entry into the eye problematic. A small retinotomy performed with the vitreous cutter probe located at the most anterior, superior pole of the subretinal bubble usually works well for evacuation.

Postoperative

The most common postoperative complication of PR is new and/or missed retinal breaks (Table 4.6) [3, 9, 11–18]. Most of these are discovered during the first postoperative month, with between 61% and 86% being identified during this time period [19, 20]. Of new and/or missed breaks, 76% occur in the superior two-thirds of the retina. They almost invariably occur anterior to the equator and are more common in pseudophakic or aphakic eyes [20]. Missed breaks can be avoided by performing a very thorough preoperative retinal examination. The authors have found that a 78D or 90D exam of the peripheral retina is invaluable for discovering small breaks preoperatively. Additionally, cases with media opacities,

Table 4.6. Postoperative complications

New/missed breaks [3, 9, 11–18]	7–33%
Break re-opened [13, 15]	0–14%
Epiretinal membrane [9, 11–14, 16, 17]	2–11%
Proliferative vitreoretinopathy [3, 9, 11–18]	3–13%
Cataract [11, 13–15, 17, 18]	0–20%
Cystoid macular edema [14, 18]	0–8%
Delayed resorption of subretinal fluid [10, 14, 16]	0–6%
Macular hole [13, 14, 15, 17]	0–3%
Anterior ischemic optical neuropathy [14, 17]	0–2%
Endophthalmitis [13]	<1%

such as sector or spoke cortical cataracts, peripheral capsular opacification, and vitreous hemorrhage, which preclude a clear view, may be less well suited to PR. The risk of new break formation is minimized using prophylactic treatment of at-risk lesions, such as lattice patches, cystic tufts, and meridional complexes, with laser prior to gas injection. Consideration should be given to prophylactic 360° laser at the vitreous base, which has been reported to lower the rate of new/missed breaks and increase surgical success [14]. Delayed resorption of SRF is encountered in between 0% and 6% of cases [10, 14, 16]. In most instances, the original detachment was subacute or chronic, and the SRF was shifted away from the original break, trapping it in the subretinal space.

Additional reported posterior segment complications included epiretinal membrane (ERM) formation in 0% to 11% of cases [9, 11–17], PVR in 3% to 13% [3, 9, 11–18], cystoid macular edema (CME) in 0% to 8% [14, 18], macular hole in 0% to 3% [13–15, 17], anterior ischemic optic neuropathy in four cases [14, 17], and endophthalmitis in one case [13].

Late anterior segment complications include cataract formation. Although lens injury during injection is rare, late cataract presumably due to gas-lens touch is much more common. Cataract is reported in 0% to 20% of cases [11, 13–15, 17, 18], with rates depending on type and amount of gas used as well as duration of follow-up postoperatively.

New Possibilities

Surgeons continue to push the limits for detachments amenable to treatment using PR. Detachments with breaks in more than one quadrant may be repaired by augmenting the bubble size via a second injection on the first or second postoperative day, or by flattening one break over a 72-h period, then changing patient positioning to address the second area in another quadrant [21]. The treatment of detachments with large breaks has been controversial. Gas is more prone to migrate into the subretinal space, and the arc of contact may not be broad enough to tamponade the entire break. Nevertheless, reports exist of the successful use of PR for RRDs due to giant retinal tear (4 of 5–80%), retinal dialysis (4 of 4–100%), and other large breaks [22–24]. These reports demonstrate that PR can be effective for cases with large breaks if they are located superiorly and lack significant vitreoretinal traction. Pneumatic retinopexy has generally been avoided for RRD with breaks in the inferior 4 clock hours of the fundus. Inverted PR has been reported in phakic detachments. Utilizing 8 h of "head dangling" positioning followed by laser retinopexy or cryopexy, the single surgery reattachment rate was 9 of 11 (82%) [25]. It is evident that although PR has an "ideal" scenario for its chief indication, the technique is more widely applicable in certain select cases for those with multiple breaks, large breaks, and even breaks located in the inferior four clock hours.

Results

Anatomic Results of PR

The reported primary anatomic success rates of PR vary widely in published series, ranging from 61% to 90% with an overall single procedure combined rate of 75.5% – 918/1,215 cases (Table 4.7) [3, 9–18, 26–29]. There does not appear to be a difference between the selection of tamponade agents with respect to anatomic outcome – with filtered air, SF_6, and C_3F_8 having similar reported results. There is no trend toward higher success rates over time. The 84% primary anatomic success rate reported by Hilton [9] is similar to the reports by Abecia [15] and Eter [28], with success rates of 82% and 86%, respectively. The overall final anatomic (with re-operations) success varies between 87% and 100% in this group of

Table 4.7. Anatomic and visual outcomes

Author	Year	Number of patients	Technique	Primary success	Final success	Visual outcome (for macula-detached subset)
Hilton [3]	1986	20	0.3 cc C_3F_8 0.6 cc SF_6	90%	100%	
Hilton [9]	1987	100	C_3F_8 or SF_6	84%	98%	65% 20/20–20/50
Chen [16]	1988	51	0.3 cc C_3F_8	63%	–	35% 20/20–20/50
Lowe [12]	1988	55	0.3–0.5 cc C_3F_8	82%	98%	

Table 4.7 (continued)

Author	Year	Number of patients	Technique	Primary success	Final success	Visual outcome (for macula-detached subset)
Algvere [26]	1988	58	C_3F_8	64.0%	95%	74%
Tornambe [13]	1989	103	C_3F_8 or SF_6	73.0%	99%	80% 20/20–20/50[a]
Sebag [27]	1993	45	0.8 cc Air	86.7%	100%	64% 20/20–20/50
Trillo [10]	1993	55	0.6 cc SF_6 0.3 cc C_3F_8	83.6%	100%	
Tornambe [14]	1997	302	C_3F_8 or SF_6	68%	95%	
Han [17]	1998	50	SF_6, C_3F_8, Air	62%	98%	63% 20/20–0/50
Lisle [18]	1998	48	0.6 cc SF_6 0.3 cc C_3F_8	83%	100%	65% >0.4
Assi [11]	1999	31	SF_6 or C_3F_8	61%	87%	45% >6/12[a]
Abecia [15]	2000	219	0.5 cc SF_6	82%	98.9%	
Eter [28]	2000	78	0.4 cc SF_6	86%	98.7%	
Overall average				75.5%	97.4%	

[a] Macula detached <2 weeks

reports, with a cumulative success rate of 97.4%. When PR fails, the most common second technique employed was SB; however, a number of patients undergo either pars plana vitrectomy (PPV) alone or PPV with SB.

Visual (Functional) Results

The functional results of PR reported in the literature vary widely, so that it is difficult to compare and summarize the data. For those patients with macula-involved detachments, final best-corrected visual acuity greater than or equal to 20/50 was achieved in between 35% and 80% of cases. The wide variation in these numbers probably represents variation in the duration of macular detachment. Studies that categorized detachments of less than 2 weeks of macular involvement tended to have better outcome averages. Overall, most series reported averages for best-corrected visual acuity greater than or equal to 20/50 following macula-involving detachments to be about 65%.

When examining the data for patients without preoperative detachment of the macula, 86% to 88% will have the same or improved best-corrected visual acuity [9, 13]. However, between 12% and 14% of patients will lose two or more lines of best-corrected visual acuity. Surgical failures and complications were the reason for vision loss in most instances.

Reasons for Failure

The causes of anatomic failure following PR have been examined in several series [19, 30]. New retinal breaks are the most commonly cited reason for failure; however, missed pre-existing breaks are commonly grouped together because of the difficulty differentiating the two. New and/or missed breaks occur in between 7% and 33% of reported cases [3, 9, 11–18] and account for 48% to 73% of surgical failures. Failure to close the initial break and re-opening of the initial break are typically grouped together. This problem is encountered in 5% to14% of cases [13, 15] and is responsible for 25% to 51% of surgical failures. PVR occurs postoperatively in 3% to 13% of cases in reported series [3, 9, 10–18], though fortunately, it is a rare cause of failure.

Discussion

Rhegmatogenous retinal detachment is a very heterogeneous disease state, and, as a result, comparison of surgical results of different techniques is difficult. Certainly PR, primary PPV, and SB each have a place in a surgeon's armamentarium of treatment modalities. The use of PR is limited by anatomic considerations – number, location and size of breaks, chronicity, preoperative PVR, and lens status – while primary PPV and SB techniques can be used for most cases of RRD. Nevertheless, PR has advantages in certain clinical situations.

Advantages of PR

Given an optimal clinical scenario, PR has several advantages over primary PPV and/or SB for the repair of a RRD. Pneumatic retinopexy is usually performed in the office or as a brief procedure in an outpatient surgical facility. In a multicenter trial reported by Tornambe [13], the average number of hospital days including re-operations was 0.6 days for the PR group and 2.7 days for the SB group. The physician spends less time waiting for availability of the operating room, performing the procedure, and performing post-operative hospital rounds. It should be noted, however, that since this publication in 1989, the majority of procedures, including PR, primary PPV, and SB, are now performed in an outpatient setting.

With PR, the patient generally experiences less pain, and there is a quicker recovery in the more comfortable setting of home. There is also a significant economic advantage to the patient and the insurer in terms of cost savings by avoiding the operating room, anesthesia, and hospitalization expenses. It is estimated that the cost of PR is between 25% and 50% of that of SB, including re-operations [14].

Pneumatic retinopexy is a technically easy procedure. There are very few significant intraoperative complications. When they do occur, they generally involve improper location of the injected air or gas, generally into the subretinal space. This is seen in only 0% to 4% of cases [12–15], however, postoperative complications of PR are rare, with the exception of new and/or missed retinal breaks. But ERM, CME, macular hole, and PVR rates are more than or equal to published risk rates for SB and PPV [3, 9, 11–17, 31–60].

Functional visual results of the three techniques is an area of significant controversy. It is well recognized that PR and primary PPV both avoid the significant induced myopia and astigmatism associated with SBs. The induced changes in refractive error can, in some cases, produce significant anisometropia, requiring contact lens use or even refractive surgery. A large multicenter trial comparing SB and PR found a significant visual benefit with PR. For eyes with preoperative macular detachment of less than 2 weeks duration, the percentage of patients achieving 20/50 or better best-corrected visual acuity was 80% for PR and 56% for SB [13]. Two retrospective, comparative series by Han [17] and McAllister [61], however, found no statistically significant difference in visual outcomes between the two procedures. Similar data for primary PPV is unavailable for a meaningful comparison; however, the positive impact of the clearance of vitreous floaters and debris cannot be underestimated.

Disadvantages of PR

Anatomical success is one key issue regarding the outcome of surgical techniques for the repair of RRD. The cumulative initial success rate for the surveyed papers was 75.5% (Table 4.7) [3, 9–18, 26–29], with a final overall success of 97.4%. This is lower than reported rates for PPV (85%) [31] and SB (88% – 1,440/1,630) [62–67]. The case selection for PR typically involves simple anatomy, so matching for similar cases done with PR or SB might uncover a larger disparity in success rates. A prospective, randomized multicenter trial comparing PR with SB found a lower primary success rate with PR (73%) versus SB (82%), but a similar final success rate of 99% versus 98%, respectively [13]. A retrospective comparative series by McAllister [61] found a higher success rate for SB (96%) compared with PR (71%). However, when aphakic and pseudophakic eyes with open posterior capsule were excluded, the success rate for PR improved to 81%. A similar study by Han [17] found a higher anatomic success rate for SB (84% versus 62%), but an equal final success rate of 98%. The data does support the fact that for RRD, SB and primary PPV offer superior initial success rates, yet equivalent final anatomic success rates.

Pneumatic retinopexy has a lower initial success rate for two major reasons: (1) re-opening of the original break; and (2) new and/or missed retinal breaks. Both SB and primary PPV permanently relieve vitreoretinal traction, and, therefore, break re-opening is a relatively rare phenomenon. With PR, there is no relief of traction, so that the laser- or cryopexy-induced chorio-retinal adhesion must be strong enough to overcome this tractional force on the retina. New and/or missed retinal breaks are more commonly encountered with PR than with PPV or SB. One contributing factor for missed breaks may be the extent of retinal examination performed with each technique. All patients undergo extensive retinal examination prior to any of the three surgical procedures, but SB and primary PPV provide additional examination opportunities. During SB, an exam under anesthesia with open conjunctival scleral depression is routinely performed, thereby allowing discovery of previously missed breaks. PPV, especially when performed under wide-field viewing, allows extensive, high-magnification, peripheral examination under anesthesia. In addition, PPV will remove media opacities, such as an opacified posterior capsule, vitreous hemorrhage, or vitreous debris, resulting in a superior view of the retinal periphery.

New retinal breaks do occur following PR. It is postulated that a gas bubble within the vitreous cavity creates additional vitreoretinal traction, particularly when the bubble is positioned between the retina and posterior hyaloid face. These breaks may occur in any quadrant, but 76% are located in the superior two-thirds of the retina, and 52% are located within 3 clock hours of the original causative break. The majority (59%) of new breaks occur during the first postoperative month [13]. Prophylactic 360° peripheral barricade laser has been advocated to reduce the risk of new and/or missed retinal breaks. Tornambe [14] found a single operation success rate of 55% when focal retinopexy was employed compared with 85% for patients following 360° retinopexy. Presumably, this difference was due to a lower number of failures due to new and/or missed breaks in the 360° retinopexy group.

Conclusion

Pneumatic retinopexy certainly has a place alongside SB and primary PPV in the constellation of surgical techniques for the repair of RRD. It is evident that PR has a lower single procedure primary anatomic success rate than the other techniques in most clinical situations. During informed consent discussions with patients, when describing the risks and benefits of the various treatment options, PR shines forth. Patients frequently choose PR, in spite of its lower primary success rate, because of the perceived benefit of less pain, less time away from work and favored activities, less surgical risk, and lower costs. It is reasonable to try PR first in favorable situations, then to proceed with SB or PPV, if and when success is not obtained. The final overall success rate with re-operations for the three procedures is equivalent. As a result, PR should have a place in each vitreoretinal surgeon's repertoire of techniques for the repair of RRD.

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Vitrectomy for the Primary Management of Retinal Detachment

Stanley Chang

Introduction

Treatment options for the primary management of rhegmatogenous retinal detachment have increased in recent years. The "gold standard" approach has been the use of scleral buckling. The success of the scleral buckle operation depends on two factors – the ability of the surgeon to find and to localize all of the retinal breaks and the surgical procedure to successfully close them on the buckle without surgical complications. However, there are even varying approaches and differing surgical techniques in the scleral buckle operation. Controversy regarding surgical aspects, such as encirclement versus localized buckle and drainage of subretinal fluid versus non-drainage, persist among surgeons. In the end, the success rates for anatomic retinal reattachment are high, ranging in the 83–95% range after a single operation. Careful examination of the retina combined with a compact surgical explant operation that closes the retinal breaks as pioneered by Harvey Lincoff and Ingrid Kreissig [1–3] is a very effective method for the treatment of retinal detachment.

Newer techniques have sought to minimize the role of the scleral buckle by either closing the retinal break temporarily internally or externally until a chorioretinal adhesion can form around it. These techniques include pneumatic retinopexy, temporary balloon buckling, or vitrectomy. Both pneumatic retinopexy and balloon buckling may be useful and most successful in selected cases, offering a less invasive surgical procedure and avoid permanently implanted material around the globe. The improved visual outcomes in patients with macula-off retinal detachments treated with pneumatic retinopexy compared with those treated with scleral buckling is debatable. These two procedures do not relieve the vitreous traction permanently and, thus, inherently have a higher primary failure rate compared with scleral buckling. Vitrectomy has appeal for retinal surgeons because of the ability to remove vitreous traction internally, reducing the forces that cause subretinal fluid to develop. It is usually easier to be sure that all of the retinal breaks are found intraoperatively. Annoying vitreous floaters are removed, and, in pseudophakic eyes, the refractive error is changed minimally. These are attractive benefits that seem to result from vitrectomy, and, increasingly, this approach is taken by younger vitreoretinal surgeons in practice.

The choice of the surgical procedure will be dependent on the surgeon's comfort and experience with each of the available procedures. The preference for the procedure should lead to the best chances for the optimal outcomes – an attached retina with excellent final visual result that synchronizes with the fellow eye. This chapter will discuss my personal views on the indications, surgical techniques, and published results of the management of primary retinal detachment with vitrectomy.

Indications

The indications for the choice of vitrectomy as the primary method for managing retinal detachment is quite varied among surgeons. Some believe that it should be used in every case, and others feel that a scleral buckle should be attempted first in all cases before vitrectomy is done. Until the clinical evidence can be established for each end of the spectrum, I have chosen an approach that is somewhat more conservative and that balances the risks of vitrectomy with its benefits.

Table 5.1. Indications for vitrectomy in primary retinal detachment

1. Vitreous opacity – hemorrhage, pigment/debris, uveitis, asteroid hyalosis
2. Undetected retinal breaks
3. Large posterior retinal tears usually associated with lattice degeneration
4. Posterior retinal breaks in high myopia, colobomas, and staphylomas
5. Failed pneumatic retinopexy
6. Subretinal gas
7. Selected cases of retinoschisis
8. Giant retinal tears
9. Proliferative vitreoretinopathy
10. Retinal detachment following open globe injury

Primary management with vitrectomy is reserved for selected types of retinal detachment that are more difficult to manage with scleral buckling alone. These types of retinal detachment are often more complicated using an external episcleral approach and are listed in Table 5.1. An internal approach allows better visualization of the retinal breaks, better removal of traction on the retina, or better repositioning of the detached retina (Figs. 5.1, 5.2). In some cases, an encircling scleral buckle may also be necessary to support the area of the vitreous base. A more detailed discussion of each situation follows below.

Opacification of the vitreous may be sufficient to prevent adequate examination of the peripheral retina. These opacities may result from vitreous hemorrhage, pigment or debris, uveitis, or asteroid hyalosis. When a dense vitreous hemorrhage is present, there is a higher chance that proliferative vitreoretinopathy (PVR) will develop. The reason for this is not completely understood. Does the hemorrhage introduce cytokines that activate the proliferative processes, or is it the type of retinal tears (usually large flap tears)

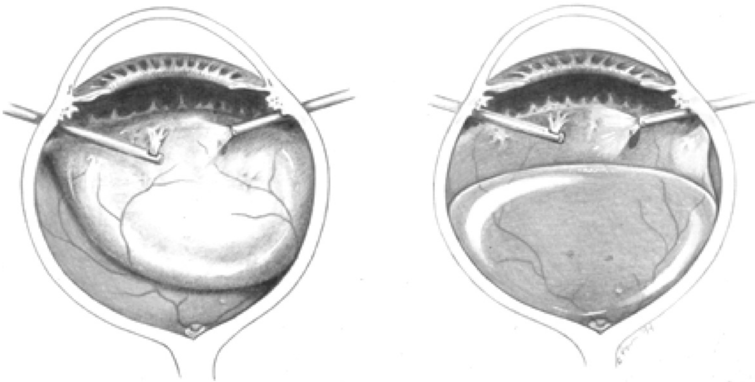

Fig. 5.1. When the retinal detachment is bullous (*left*), adding perfluorocarbon liquid after removing the central cortical vitreous can help to flatten and immobilize the retina, creating additional space to excise the peripheral vitreous. There is less likelihood of damage of the peripheral retina as instruments enter through the sclerotomy incisions

that allow more retinal pigment epithelial cells to be liberated? Clearing the vitreous opacity allows more accurate identification of the retinal breaks and removal of stimulatory factors for PVR.

In approximately 1–4% of retinal detachments, retinal breaks are not visualized. There are several reasons. In some cases, despite careful funduscopic examination with indirect ophthalmoscopy and contact lens examination, retinal breaks causing the retinal detachment cannot be found. Eyes that have undergone cataract surgery (aphakic or pseudophakic) are more likely to have small retinal breaks in the vicinity of the vitreous base. In other cases, anterior segment changes limit the visualization of the fundus. These include cortical lens opacities in phakic eyes, or capsular phimosis or peripheral capsular opacities in pseudophakic eyes. Microcornea or a small pupil may also prevent adequate evaluation of the retina. There is a worse prognosis in cases where a retinal break cannot be found when treated with scleral buckling alone.

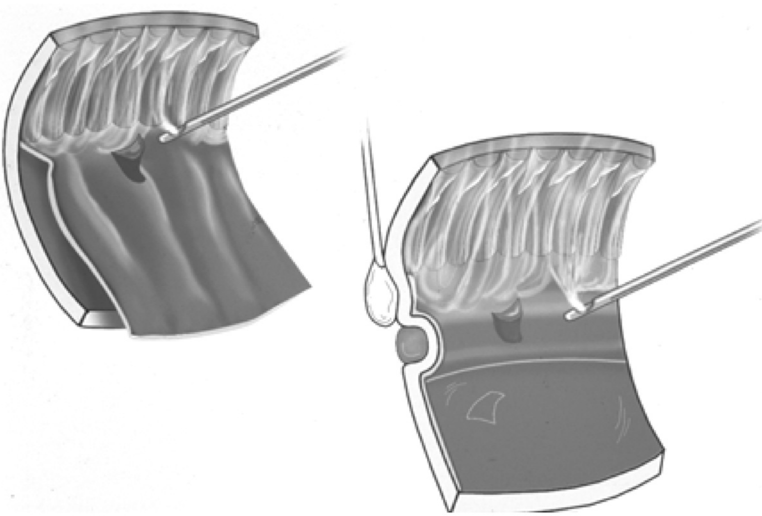

Fig. 5.2. The vitreous is excised along the vitreous base and traction around the flap of the retinal tear is removed. Scleral depression is used to assist in visualizing the anterior vitreous base

Failure of retinal reattachment has been reported for 31–43% of these cases [4, 5]. Vitrectomy allows better visualization of the peripheral retina intraoperatively and offers a better chance to identify the breaks and treat them.

Some retinal detachments are associated with large posterior retinal breaks, usually in lattice degeneration (Fig. 5.3). These breaks may occur in lattice degeneration with differing anteroposterior levels. Sometimes a portion of the retinal tear extends posterior to the equator. When the breaks are multiple, with long patches of lattice degeneration, a wide posterior scleral buckling element may be difficult to suture to the sclera and may deform the shape of the globe, resulting in diplopia and anisometropia. Often these eyes are highly myopic with thin scleral tissue. Thus, it may be preferable to select vitrectomy and endophotocoagulation to reduce the amount of surgical trauma in these cases.

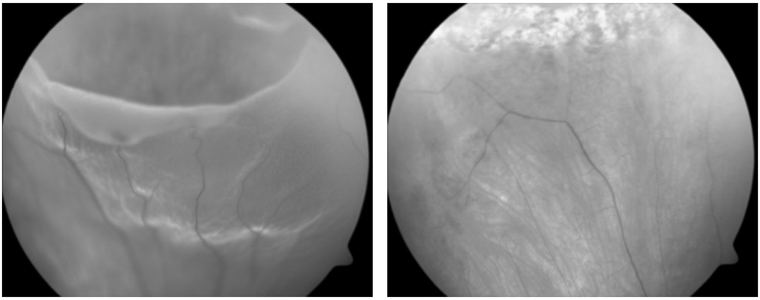

Fig. 5.3. A large posterior retinal tear developing along postequatorial lattice degeneration (*left*). Postoperatively after the gas bubble has reabsorbed, the retinal tear is sealed by laser photocoagulation (*right*). No scleral buckle was placed, because of the tear's posterior location

Posterior retinal breaks, such as macular holes in highly myopic eyes and retinal breaks within the colobomatous area, are best managed initially with vitrectomy and gas tamponade. Placing a scleral buckle in these eyes may be difficult and more likely to have complications.

Our experience in cases of failed pneumatic retinopexy often reveals that vitrectomy with or without scleral buckling is necessary. There may be persistent vitreous traction or even new retinal breaks that are better managed with vitrectomy. In cases that fail from gas bubbles expanding in the subretinal space, the best way to manage this situation is vitrectomy with the use of perfluorocarbon liquids to express the bubble from the subretinal space.

Full thickness retinal detachments are seen in patients with retinoschisis when both, an inner layer and an outer layer retinal break, are present. In selected cases where the outer layer breaks are posteriorly located, vitrectomy may be preferable to scleral buckling. In cases where the breaks are peripherally located, scleral buckling is effective in reattaching the retina.

Giant retinal tears and retinal detachment with PVR are complex forms of retinal detachment that are routinely managed with vitrectomy and scleral buckling. Giant tears with an inverted posterior retinal flap are best repositioned with perfluorocarbon liquids after core vitrectomy. Giant tears that do not have a rolled posterior flap might be managed with scleral buckling alone. While PVR usually develops as a complication of prior retinal surgery, it is occasionally seen primarily. Such situations might result from a delay in diagnosis, or in eyes with vitreous hemorrhage or choroidal detachment. Vitrectomy is necessary if the epiretinal traction prevents the retinal breaks from flattening on the scleral buckle.

Surgical Technique

Advances in surgical instrumentation and technique have made vitrectomy a safer and more effective procedure in an eye with a detached, mobile, elevated retina. Critical components of the surgical instrumentation should include a high-speed vitreous cutter (2,500 cuts/min), a panoramic viewing system, and perfluorocarbon liquids. High-speed vitreous cutters allow shaving of the vitreous near mobile retina. The vitreous traction can be relieved around the tear, and it is possible to shave vitreous around areas of lattice degeneration, even with a mobile retinal detachment. The intraoperative use of perfluorocarbon liquids flattens the retinal detachment and reduces the potential for iatrogenic retinal breaks, as the vitreous instruments pass in and out of the sclerotomy sites. Also, the perfluorocarbon liquids reduce the mobility of the retina, as the cortical vitreous is shaved near the vitreous base (Figs. 5.1, 5.2). Panoramic viewing allows better visualization of the periphery and helps to localize the retinal tears or breaks. This is particularly useful in pseudophakic eyes with a small optical aperture, or in eyes with microcornea.

The surgical algorithm starts with a decision about the necessity for a concomitant scleral buckle. In aphakic or pseudophakic eyes, where the retinal breaks are small and located in the vitreous base, a low encircling scleral buckle is used to reduce vitreous traction that inherently cannot be removed. A scleral buckle should also be used to support inferiorly located retinal breaks. In general, scleral buckling is not needed if the vitreous attachments can be completely relieved around the retinal break. These are usually retinal tears that are located posterior to the vitreous base. A 2.0-mm or 2.5-mm encircling band with low to moderate elevation can be placed to support the vitreous base region.

After preplacing the scleral buckle, the vitrectomy proceeds with removal of the central vitreous. If the retinal detachment is very bullous and close to the posterior surface of the lens, it is possible to drain subretinal fluid before entering with the vitrectomy instruments. In my experience, this has never been required. In cases where the retinal detachment is bullous or the detachment threatens to involve the macula, it is helpful to use some perfluorocarbon liquid to flatten the posterior retina. Approximately 1–1.5 ml of liquid is used, and this can prevent the retinal detachment from becoming more bullous or a further detachment anteriorly due to the introduction of the surgical instruments. The vitrectomy instrument is set using high cutting rates (2,000–2,500 cuts/min) with relatively low aspiration settings to reduce the chance of causing iatrogenic retinal breaks during the vitrectomy. At this point, a wide-field contact lens is used to examine the retina and to localize the retinal breaks. In most instances, the breaks are readily appreciated, but occasionally, the retinal breaks will be found after scleral depression and shaving of the basal vitreous. Occasionally retinal breaks can also be seen by observing the "schlieren" from subretinal fluid passing through the retinal break as additional perfluorocarbon liquid is injected.

It is important to excise much of the peripheral vitreous at the vitreous base to reduce remaining anterior tractional forces on the retinal break. It is contraction of residual basal vitreous that leads to anterior foreshortening of the retina. After careful scleral depression and peripheral vitreous excision, it may be helpful to lightly mark the retinal breaks with endodiathermy so that they will be visible under air. The scleral buckle is then adjusted to the desired height, and perfluorocarbon liquid is added until the level reaches the level of the retinal tears. Endophotocoagulation is placed around the retinal breaks through perfluorocarbon liquid. In some cases, the anterior portion of the retinal break may still be detached, and the laser treatment around the anterior locations can be completed after fluid-air exchange.

Fluid-air exchange is done by placing an extrusion needle in the saline compartment near the retinal breaks as the air bubble enters the eye. The anterior retina is flattened by the air bubble, and then the perfluorocarbon liquid is passively aspirated. At the end of the exchange, the retinal tears are flattened under air with minimal or no visible subretinal fluid remaining. There should be visible photocoagulation treatment surrounding the retinal breaks. Usually two to three rows of treatment are sufficient. The eye is then flushed with a mixture of sulfur hexafluoride (25%) and air, or perfluoroethane (15%) and air, depending on the location of the retinal breaks. When retinal breaks are present inferiorly, a longer-lasting gas is used. Air alone can also be used for easier cases.

Outcomes

The increasing use of vitrectomy for the primary management of retinal detachment was studied at one hospital that compared the characteristics of the surgical procedures used in 1979–1980 with their cases 20 years later (in 1999) [6]. Of 124 eyes managed in 1979–1980, only one had vitrectomy as the primary mode of treatment. In 1999, 79 of 126 (63%) were managed with vitrectomy. The severity of cases did also differ, however, with more complex cases, such as pseudophakic retinal detachments, giant retinal tears, and proliferative vitreoretinopathy cases managed in 1999.

The rates of retinal reattachment after vitrectomy vary from 64% to 100% after a single operation [7–11]. When all the cases are combined, the retina was reattached in 87.7% (421 of 480 eyes) of eyes after one operation and 96.7% after multiple operations. The surgical techniques did vary and might explain some of the differences in anatomic outcomes. In some series, concomitant scleral buckling was done [10], but in others, a scleral buckle was not used in any of the eyes [9]. Also, vitrectomy was done only in pseudophakic eyes, compared with other series that were operated without regard to the lens status. The most common causes of failure of the primary operation were missed retinal breaks or the development of PVR. In a series of 25 failed cases analyzed for the cause of failure, missed retinal breaks were responsible for 64.3% of failures [12]. These cases were managed with vitrectomy revision with or without scleral buckling. The visual acuity outcomes are not stated in many of these reports, and it is not possible to determine if the outcomes are more favorable than in eyes treated with scleral buckling alone. Some retrospective reviews and randomized clinical studies comparing the anatomic outcomes between vitrectomy and scleral buckling as the primary operation have been reported [13–15]. In general, they report similar anatomic and visual outcomes and probably have too small a number of eyes to have sufficient power to detect a difference. A large prospective randomized study with matched retinal detachments would be required to find if there is a difference in visual acuity outcomes. Such a study would probably require hundreds of patients, since the anatomic reattachment rates are high both with scleral buckling and with vitrectomy and is currently in progress in Germany (SPR Study) [16].

There are several advantages to the use of vitrectomy in the primary management of retinal detachment. Intraocular visualization is much improved, reducing the possibility of missing retinal breaks. In one prospective study of 51 eyes undergoing vitrectomy, 7 (13.7%) eyes were found to have previously undetected retinal breaks, and additional holes were found in 21 (41%) eyes [17]. The traction on the tear is removed with vitrectomy with any vitreous debris or hemorrhage. Thus, the patient rarely sees "floaters" postoperatively. The retina is almost completely flattened at the time of surgery with the help of perfluorocarbon liquids, and there is almost no persistent subretinal fluid involving the macula. Thus, the recovery of macular function starts immediately postoperatively. Choroidal detachment is rarely seen in vitrectomized eyes. Endolaser photocoagulation is more comfortable for the patient and may cause less surgically-induced inflammation compared with cryotherapy. If a scleral buckle is used in conjunction with vitrectomy, it tends to be a smaller buckling element, especially with large posterior retinal tears. In pseudophakic eyes, there is less change in postoperative refractive error when no scleral buckle is used.

The complications of vitrectomy may affect the visual and anatomic outcome. The possibility of iatrogenic retinal breaks as a result of cutting near mobile retina or from vitreous incarceration at sclerotomy sites increases the risk of failure. A large gas bubble may be associated with glaucoma or with iris capture of an intraocular lens. Unexplained visual field defects may also occur after vitrectomy. Rarely, a retinal fold that involves the macula is seen postoperatively. The patient complains of marked distortion. Endophthalmitis is a rare but devastating complication. In phakic eyes, the postoperative progression of nuclear cataract may be the single reason that vitrectomy is not recommended routinely for every retinal detachment. In a young patient with a clear lens in the fellow eye, the loss of accommodation resulting from pseudophakia can be quite disabling. Thus, whenever possible, it is preferable to use an operation that will not increase the rate of cataract progression.

There are also economic considerations that may play a role in the choice between vitrectomy and scleral buckling as the primary treatment for retinal detachment. The cost of supplies for a scleral buckling procedure is significantly less than that of a vitrectomy. If cataract surgery is also required later, the cost difference is multiplied. The rehabilitation time is increased after vitrectomy compared with scleral buckling. In general, most of my patients are able to return to work 1 week after scleral buckling. After vitrectomy, most patients are incapacitated for 2–4 weeks because of head positioning and inability to drive. There is a prolonged recovery time, with lengthened disability. While these factors might seem small for the individual case, it is estimated that up to 30,000–50,000 retinal detachments are treated annually in the United States.

Further data will be required to define the role of vitrectomy for the management of uncomplicated retinal detachments. In particular, these studies should provide strong clinical evidence for situations where the benefits from vitrectomy are superior to scleral buckling. At the present time, the main limitation for vitrectomy in phakic eyes is the progression of nuclear cataract. Until there are better treatments developed to prevent this complication, scleral buckling remains the main treatment modality for most retinal detachments with vitrectomy as an adjunct for more complex cases.

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Minimal Segmental Buckling With Sponges and Balloons for Primary Retinal Detachment

Ingrid Kreissig

Introduction

We have known for more than 70 years that a retinal detachment is caused by a break, as Gonin postulated in 1929 [1]. The postulate is no longer in doubt; however, the discussion on how to close it is ongoing. Therefore, the best procedure to repair a rhegmatogenous retinal detachment should be one with a minimum of trauma, a maximum of primary attachment, a minimum of reoperations with a minimum of secondary operations, e.g., cataract, glaucoma, etc., and a maximum of long-term visual function.

By the beginning of the twenty-first century, four main surgical techniques had evolved to attach a primary rhegmatogenous retinal detachment, i.e., cerclage with drainage, pneumatic retinopexy, primary vitrectomy, and minimal segmental buckling without drainage (extraocular minimal surgery). All four procedures have one issue in common: to find and close the leaking break that caused the retinal detachment and that would cause a redetachment if not closed. This issue is independent of (1) whether the surgery is limited to the area of the break or extends over the entire detachment and (2) whether it is performed as an extraocular or intraocular procedure.

Since the rhegmatogenous detachments present a wide range of findings, each of the four procedures could cover a specific type of detachment. However, the indication of each is somehow in a gray zone, since de facto it depends on the expertise of the individual detachment surgeon.

In the following, minimal segmental buckling without drainage of subretinal fluid will be described: its origin, subsequent development of two variations and their specifics, applicability, limits, complications, anatomical and functional results, and the disadvantages and advantages of this extraocular minimal surgery.

Origins of Minimal Segmental Buckling Without Drainage

Minimal segmental buckling without drainage for repair of a primary rhegmatogenous retinal detachment is an extraocular technique in which the buckle and the coagulations are limited to the area of the break. The two components of this procedure can be traced back over several decades. The present minimal surgery developed in small steps over the years. Eliminating drainage of subretinal fluid and applying the surgery only in the area of the break was a change from treating the entire extent of the detachment to a surgery of the retinal break (Fig. 6.1).

For the first time since Gonin (1929), the coagulations were limited to the break [1]. However, the advantage of this limited and focused treatment was given up over the years, and coagulation of the entire periphery of the detached retina again was recommended to create a secure barrier against redetachment [2, 3]. Coagulating limited to the leaking break was taken up again – for the second time – by Rosengren in 1938 [4]. However, with this procedure, redetachments occurred because the intraocular duration of the air bubble was sometimes too short for a sufficient adhesion to develop around the break. Consequently, the barrier concept was integrated again into the treatment of retinal detachment. This resulted in coagulations over the entire retinal periphery, and, subsequently, a circumferential buckle was added by Schepens in 1957 [5] and Arruga in 1958 [6]. Thus, the cerclage operation with drainage of subretinal fluid evolved.

Yet, drainage, which was applied with this procedure, represented a dangerous and vision-threatening complication. The procedure

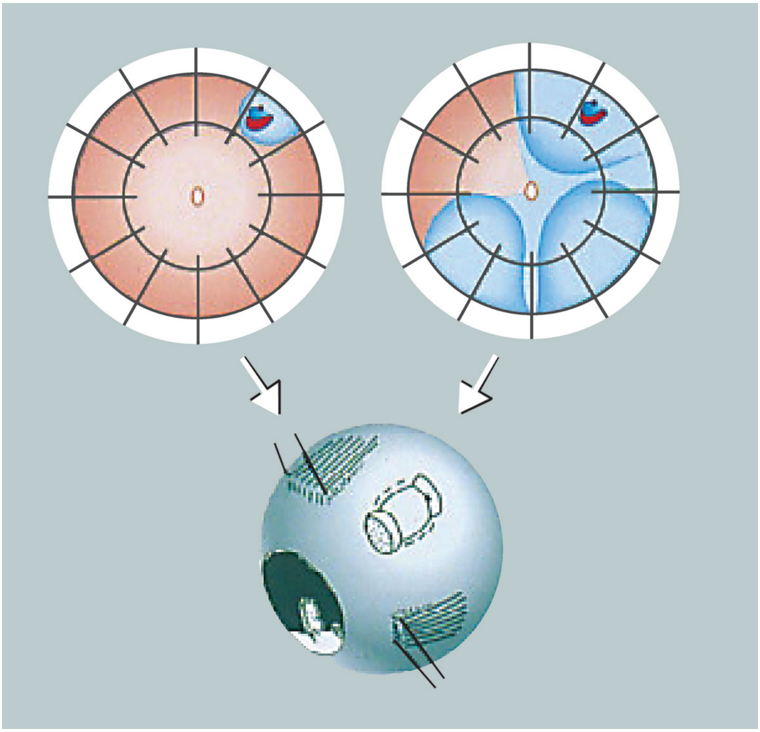


Fig. 6.1. Minimal segmental buckling without drainage, so-called extraocular minimal surgery. The treatment is limited to the area of the break and not determined by the extent of the detachment. The small (*top left*) and the more extensive detachment (*top right*) are caused by the same horseshoe tear at 1:00. The treatment of both is the same, consisting of buckling the tear either by a segmental sponge (as depicted) or a temporary balloon without drainage of subretinal fluid

was accompanied by serious complications, such as intraocular hemorrhages, which occurred in 15.6% of patients in our series, as reported in 1971 [7], in 16% as published by Blagojevic in 1975 [8], and in 6.9% as reported by Huebner and Boeke [9]. Additional complications consisted of choroidals in 8.6%, as reported by Toernquist and Toernquist in 1988 [10] and intraocular infection and incarceration of vitreous and retina, as described by Lincoff and Kreissig [11].

A procedure without drainage to attach the retina would eliminate two major hazards of drainage: (1) perforation of choroid with its serious complications and (2) the subsequent intravitreal injection to restore lost volume, which adds the risk of an intraocular infection.

The needed change was already "ante portas" in 1953 when Custodis [12] introduced a different approach to attach a retina. The procedure (1) eliminated drainage of subretinal fluid and the accompanying complications and (2) limited the coagulations and the buckle to the area of the break. The operation was in complete contrast to cerclage with drainage. Nondrainage of the Custodis technique was made feasible by the use of an elastic explant, the polyviol plombe, which was compressed by an intrascleral mattress suture over the detached retinal break. However, the sclera was treated by full-thickness diathermy, which subsequently proved detrimental to this exceptional technique. Due to the subsequent expansion of the compressed elastic plombe, the retinal break would be closed, and subretinal fluid would be absorbed. Thus, drainage was eliminated, and the intraoperative complications were reduced to a minimum. The simplicity of this Custodis principle was a concept of genius: "After the leaking break is closed, the pigment epithelium will pump out subretinal fluid and attach the retina." But despite all, this exceptional technique was nearly abandoned, not because it did not work, but because of unexpected serious postoperative complications caused by the polyviol plombe compressed over full-thickness and diathermized sclera. The diathermized sclera became necrotic, and, if bacteria were present under the compressed explant (polyviol), a scleral abscess and perforation could result. In 1960, the Boston group [13] reported serious postoperative complications after the Custodis procedure, i.e., scleral abscess and endophthalmitis requiring even enucleation. As a result, this exceptional procedure was abandoned in the United States and in Europe.

Actually, this was not true for everybody in the United States – not for Lincoff in New York. He had observed complications as well, but, on the contrary, did not give up the Custodis method. Instead, he was convinced of the logical approach and simplicity of the new Custodis procedure. Therefore, in the subsequent years, he with his group replaced diathermy with cryopexy [14, 15] and the polyviol plombe with a tissue-inert silicone plombe – the Lincoff sponge [16]. The operation was called the modified Custodis procedure and was subsequently named the cryosurgical detachment operation. The technique represents an extraocular approach, since drainage was eliminated, and the cryosurgery and the buckle were limited to the area of the break. The procedure is the basis for today's extraocular minimal surgery for a retinal detachment.

Why Was Acceptance of the Cryosurgical Operation Delayed?

There were doubts that limited its acceptance:

1. Was the cryosurgical adhesion strong enough? This was eventually confirmed by extensive animal experiments by Kreissig and Lincoff [17, 18]. It was proved that cryopexy induces a sufficiently strong adhesion in 5 days and reaches maximum strength after 12 days.
2. Would this spontaneous or "magical" disappearance of subretinal fluid occur by tamponading the leaking break ab externo with an elastic buckle, even if the break is still detached over the buckle at the end of surgery? This was the most difficult issue to accept. Why? Because in this situation, the surgeon has to leave

the operating table with the retina still detached, in contrast to the one after drainage or the injection of a gas bubble after drainage, in which case the retina is already attached at the table. Following such an operation, the surgeon can feel relaxed and, as often said, "sleep better." However, the secrets of success with nondrainage are: first, the surgeon has to be convinced that all of the breaks have been found and tamponaded sufficiently, and, second, a spontaneous attachment on the next day will confirm that all of the breaks were found and tamponaded sufficiently. However, this will be the case only in retrospect, i.e., hours after surgery combined with postoperative concern on the part of the surgeon. However, by performing drainage, often explained as being done for the sake of the surgeon or the patient, the retina might be attached at the table only temporarily, due to the drainage alone.

As a consequence, the "conditio sine qua non" for spontaneous attachment after nondrainage is that all of the leaking breaks have been found and tamponaded sufficiently intraoperatively. Otherwise, the spontaneous or "magic" disappearance of subretinal fluid will not occur. Other questions were:

3. Will a buckle that is unsupported by an encircling band persist?
4. Is the prophylactic value of a cerclage needed for long-term retinal attachment?

Minimal Segmental Buckling With Sponges and Balloons Without Drainage (Extraocular Minimal Surgery)

Specifics

This surgery is derived from the cryosurgical detachment operation of Lincoff, introduced in 1965 [16], which brought about two major changes: (1) the change from intraocular to extraocular surgery, since drainage of subretinal fluid was omitted and (2) the change from a surgery of the detachment to a surgery of the retinal break. The retinal break represented the only issue of the new surgery.

In subsequent years, the preconditions for this specific break surgery were further improved by better fundus examination techniques: binocular indirect ophthalmoscopy, as developed by Schepens, biomicroscopy, as introduced by Goldmann, development of various direct and indirect contact lenses, the 4 Rules for finding the primary break [19, 20], and the subsequent 4 Rules for finding a missed break in an eye requiring reoperation [21, 22]. Today, these 8 Rules represent essential guidelines for the detection of the leaking break in a detachment, which is the precondition for surgery limited to the area of the break. By performing this kind of a minimal extraocular surgery, the time required for a retinal detachment operation became dramatically reduced; however, the time needed for preoperative study increased.

If retinal attachment did not result within days following surgery, the logical questions had to be: (1) Has a break been overlooked? (2) Is the break that was buckled still leaking due to an inadequate tamponade? Both causes of failure are iatrogenic. Thus, one can understand why an operation that would provide retinal attachment on the table and additional prophylaxis for overlooked breaks by encircling might be preferred by some surgeons.

Optimal Orientation of a Segmental Buckle

Because the retina is fixed at the ora serrata and at the disk, when detaching, it tends to form radial folds. A circumferentially oriented buckle will augment, or at least preserve, the radial folds because it shortens the circumference of the globe, causing redundant retina circumferentially. The resulting radial folds tend to aggravate and align with a retinal break, producing what is termed "fishmouthing" of the retinal break (Fig. 6.2). The fishmouthing, in turn, provides a path for vitreous fluid to enter the subretinal space, causing failure. The logical approach to filling the potential

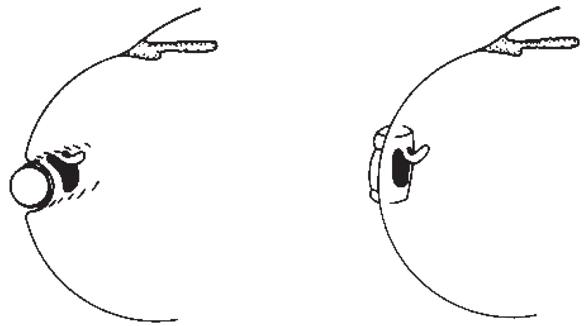


Fig. 6.2. Optimal orientation of segmental buckle as tamponade of horseshoe tear. *Left:* Using a *circumferential buckle*, the horseshoe tear is not tamponaded adequately. The operculum, an area of future traction, is not on the ridge of the buckle, but on the descending slope. In addition, there is a risk of posterior radial folds ("fishmouthing") with subsequent leakage of the tear. *Right:* A short *radial buckle* 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

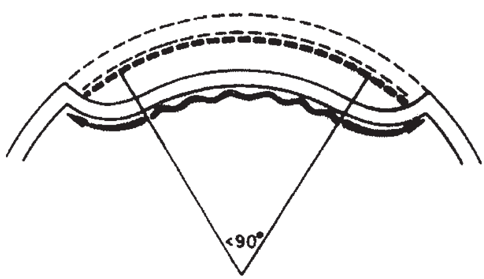


Fig. 6.3. Limit of an optimal circumferential buckle. When applying a circumferential buckle, radial folds are less likely if the buckle is not longer than 90°. If the circumferential buckle is less than 90°, the induced radial folds, caused by the constriction of the globe, will be just compensated by the two sloping ends of the buckle

fold at the posterior edge of a horseshoe tear is a radial buckle. A radial buckle supports the operculum and, at the same time, closes the posterior edge of the break, avoiding fishmouthing [23]. Goldbaum et al. [24] calculated that when applying a circumferential buckle, radial folds are less likely if the buckle is not longer than 90° (Fig. 6.3). If the circumferential buckle is less than 90°, the induced radial folds, caused by constriction of the globe, will be compensated by the sloping ends of the buckle.

The radial buckle is advantageous because it: (1) places the entire break on the ridge of the buckle; (2) counteracts fishmouthing of the break and the risk of posterior leakage; and (3) provides optimal support for the operculum, counteracting future traction and the risk of anterior leakage. Therefore, whenever possible, the sponge should be oriented with its long axis in a radial direction of the break. Multiple radial buckles can be used if the breaks are separated by approximately $1^1/_2$ clock hours. When a circumferential buckle is necessary, the greater the length of the buckle, the more likely radial folds will result. Consequently, the shorter the circumferential buckle, the better it is.

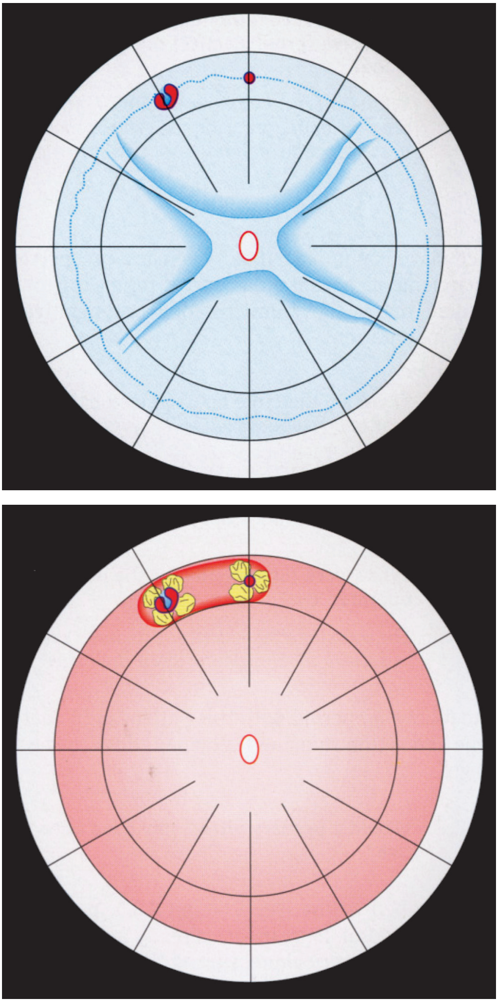
Thus, minimal segmental buckling or so-called extraocular minimal surgery had evolved [25, 26]. It is one of the four options today in use for treating a primary rhegmatogenous retinal detachment.

Some Basics of Surgical Technique

This surgery, performed under local anesthesia, is suitable for primary retinal detachments caused by one or several breaks. It consists of cryosurgery under ophthalmoscopic control and a sponge, preferably radially oriented, to the break. Consequently, the size of the buckle is determined only by the size of the break(s) and not by the extent of the detachment. The treatment of the two detachments, presented in Fig. 6.1, is the same and consists of a sponge buckle of equal size. After an analysis of 1,000 detachments, we found that there is one break in 50% of detachments, two breaks in 30%, and three or more breaks in 20%. Thus, after a meticulous preoperative and intraoperative search for the break, in about 50%, not more than one break has to be buckled. In addition, in general, multiple breaks are not distributed over the entire retinal circumference of the eye, but tend to be located within the quadrant of the primary break.

Optimum segmental buckling aims to fit the various sizes and configurations of retinal breaks. There can be three or four segmental buckles to circumvent a cerclage. The complications of a cerclage tend to be: anterior segment ischemia, hypertension or hypotension, uveitis, decreased retinal and choroidal blood flow and eventual unilateral pigmentary dystrophy, constricted visual field, reduction in two-point discrimination, and diminished retinal activity or a reduced amplitude of the electroretinogram [27–32].

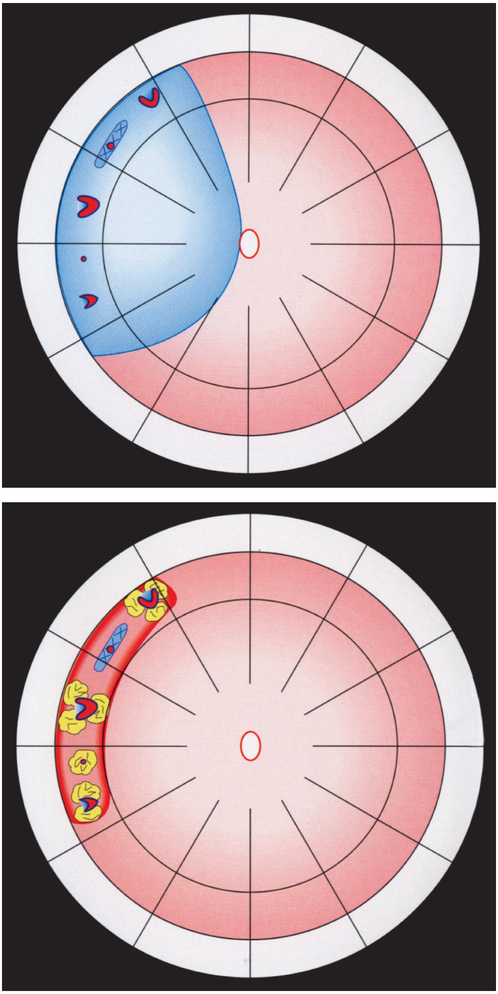
Detachments with multiple breaks and even with proliferative vitreoretinopathy (PVR) grade C1–C2 can be treated with segmental buckling and without drainage (Figs. 6.4–6.8). The segmental buckles may consist of radials, short circumferentials, or a combination of both, but without a cerclage.



a

b

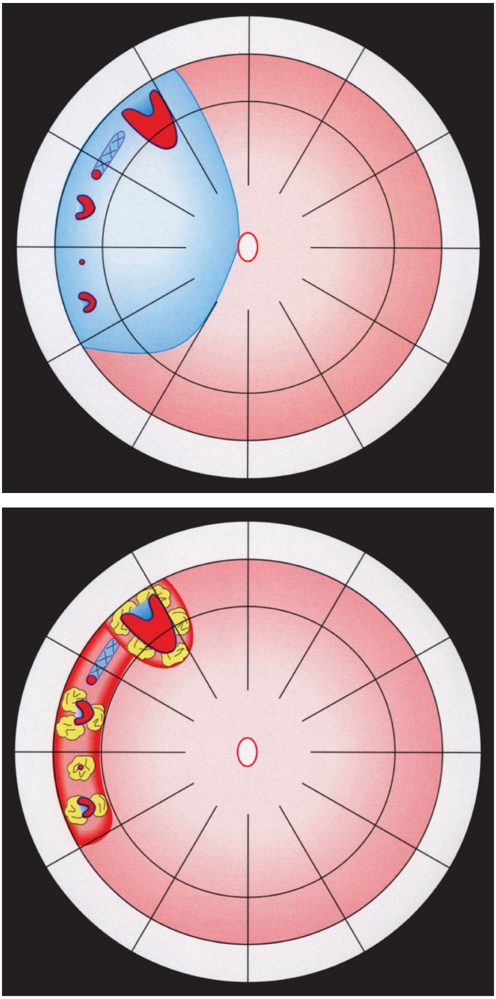
Fig. 6.4. Total detachment in pseudophakic eye. **a** There is a horseshoe tear at 11:00, a round hole at 12:00, and traction lines (insertion of the vitreous base) in the entire periphery. **b** After buckling of the two breaks by a *short circumferential* sponge buckle, the retina had attached without drainage the next morning. After 1 week, the cryopexy lesions had pigmented and subsequently the so-called traction lines disappeared. The retina remained attached during the next 15 years



a

b

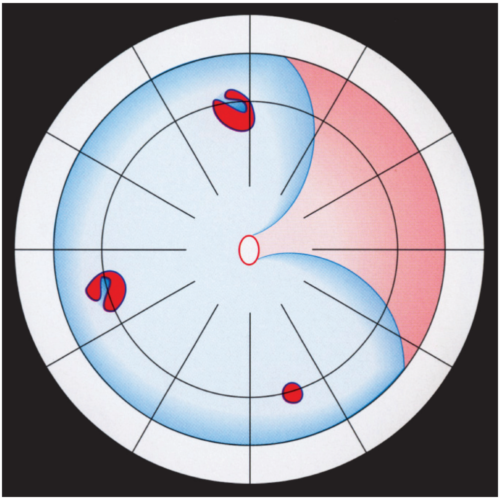
Fig. 6.5. Multiple breaks in $1^1/_2$-quadrant detachment. **a** In this detachment, there are three horseshoe tears and a round hole at the same latitude. The "round hole" in lattice degeneration at 10:00 is a pseudohole. **b** After the breaks had been tamponaded with a *short circumferential* sponge buckle (4 mm in diameter) and with precise localization of each break, the retina attached without drainage. Pigmentation around the breaks was completed after 1 week (the lattice degeneration was not treated)



a

b

Fig. 6.6. Multiple breaks of various sizes in $1^1/_2$-quadrant detachment. **a** The breaks from 8:15 to 9:30 are at the same latitude, and the "hole" within the lattice is a pseudohole. However, the horseshoe tear at 10:45 extends more posteriorly than the other breaks. **b** The breaks at the same latitude were supported by a *circumferential 4-mm sponge cylinder*, and the horseshoe tear at 10:45 was supported by a *radial 5-mm sponge cylinder* without drainage. The retina attached, and the cryopexy lesions had pigmented after 1 week. The lattice with the pseudohole was not coagulated



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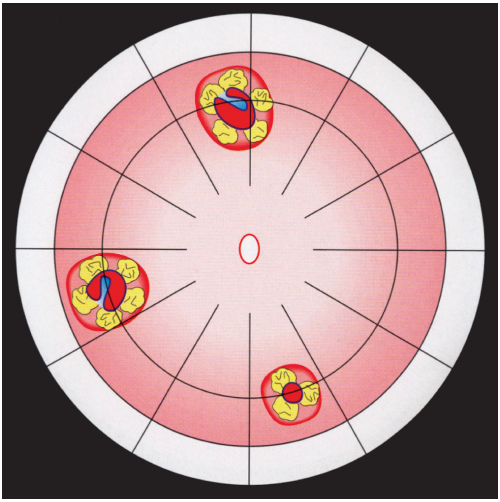
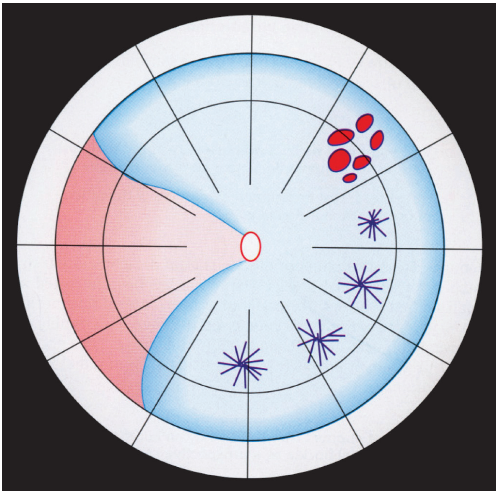
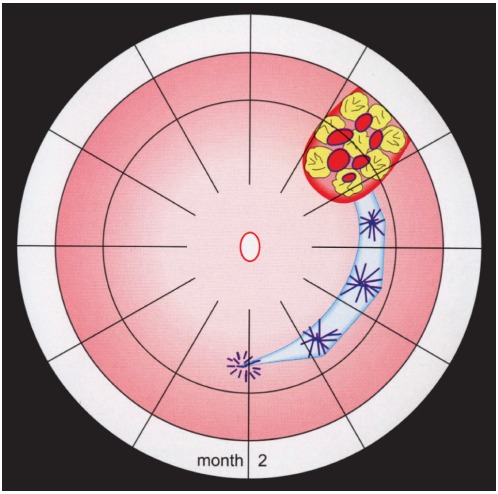


b

Fig. 6.7. Three breaks in three-quadrant detachment. **a** In this detachment, the three breaks are $2^1/_2$ to 3 clock hours apart. **b** The three breaks were treated with cryopexy and tamponaded by *three radial sponge cylinders* without drainage. The retina attached. The retina remained attached during a 14-year follow-up period. (Four radial sponges may imply the limits of radial buckles; instead, a segmental circumferential or a combination of both be preferred)



a



b

Fig. 6.8. Group of breaks in 3-quadrant PVR-C1 detachment. **a** The breaks, between 1:00 and 2:00, are with adjoining starfolds from 2:30 to 6:00 posterior to equator. No additional break was found between 10:00 over 12:00 to 1:00. **b** After buckling of breaks with *7-mm radial sponge* without drainage, the retina and macula attached, except for a residual tractional detachment located at starfolds still present 2 months postoperatively; it disappeared over time. The retina remained attached during follow-up period of 17 years

Limits of Minimal Segmental Buckling Without Drainage

There are limits to minimal segmental buckling; however, more than 90% of rhegmatogenous detachments can be treated by extraocular minimal buckling alone – the remaining 10% can be divided into three major categories.

First Category of Difficult Detachments

In this type of detachments, the limits of the minimal procedure are exceeded if the tears are posterior (in about 1%), multiple at different latitude (in 2–3%), or with a circumferential extent greater than 70° (in 1–2%). A tamponade with an expanding gas bubble without drainage represents the next level of a minimal surgery for these conditions, but it requires an intraocular injection. Consequently, in this first category, a gas tamponade will suffice. A vitrectomy will be needed for the rare situation of a giant tear of less than or equal to 150° with an overhanging flap or, as in some hands, if the tear is greater than 90°.

Second Category of Difficult Detachments

These are detachments with local vitreous traction that caused the redetachment of a horseshoe tear that had been buckled or detachments with proliferative vitreoretinopathy in more than two quadrants. In these detachments, a primary vitrectomy may be indicated. However, it is not indicated per se if the starfolds are more than 1 clock hour from the tear to be buckled. In these difficult detachments, buckling first is advisable (Fig. 6.8) [33–35]. However, if one decides upon a vitrectomy, it has to be combined with a meticulous removal of proliferative preretinal membranes and the anterior vitreous. Why? Because the additional gas tamponade, combined with the vitrectomy, can provoke anterior vitreoretinal proliferation.

Third Category of Difficult Detachments

These are represented by pseudophakic detachments; the problem lies in the opacities of the optic media after an anterior segment surgery, which precludes finding the break and the application of minimal external buckling. However, the limits of external minimal buckling in this third category are in a gray zone.

Actually, the indication for a vitrectomy in these eyes, combined with a preceding anterior segment surgery, does not depend only on the size of the tear or the presence of vitreoretinal proliferation, but also on the expertise of the surgeon in diagnostics in the presence of optical interferences. Biomicroscopy with the use of the new indirect wide-field contact lenses combined with simultaneous depression of the retinal periphery and application of the 4 Rules for finding the primary break [19, 20] might enable a limited prospective buckling and reduce the need for an invasive surgery.

Complications

There are no intraocular complications after minimal segmental buckling without drainage, except for a rare choroidal in a highly myopic eye (about 0.3%). The remaining complications are extraocular and reversible: in less than 0.5%, a buckle infection or extrusion may occur, and, in about 1%, diplopia may occur. However, diplopia after segmental buckles can be reduced to a minimum by avoiding trauma to the perimysium of the muscles during surgery, i.e., by avoiding grasping muscles with sharp instruments or uncontrolled pulling on the traction sutures. In addition, starting on the first day postoperatively, the patient should practice binocular motility exercises in all directions several times a day; this should be done independent of the state of the retina. This will avert the development of muscular adherences to the sclera or neighboring tissues and postoperative diplopia.

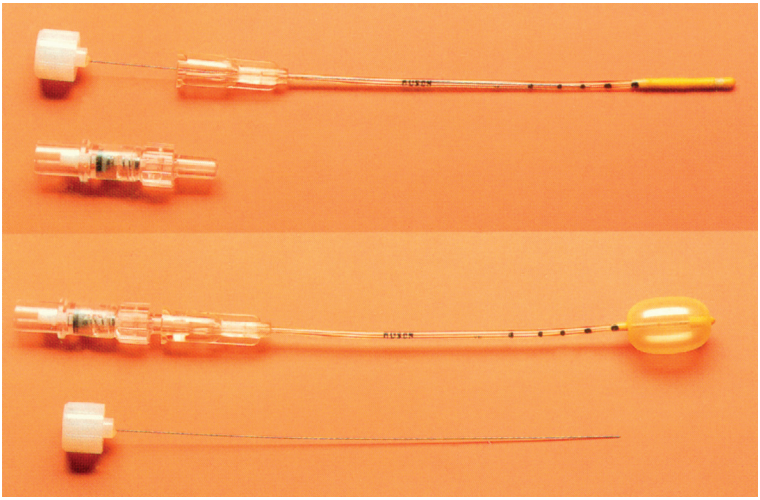


Fig. 6.9. Lincoff-Kreissig Balloon. The presented balloon has (1) a metal stylette to facilitate insertion into the parabulbar space and (2) calibrations (*black marks*) on the tube to enable a more precise determination of the position of the balloon in the parabulbar space. *Top:* Deflated balloon catheter with stylette in place; beneath it the adapter. *Bottom:* Inflated balloon (0.75 ml of sterile water) with self-sealing valve in place; beneath it the withdrawn stylette

Temporary Balloon Buckle Without Drainage

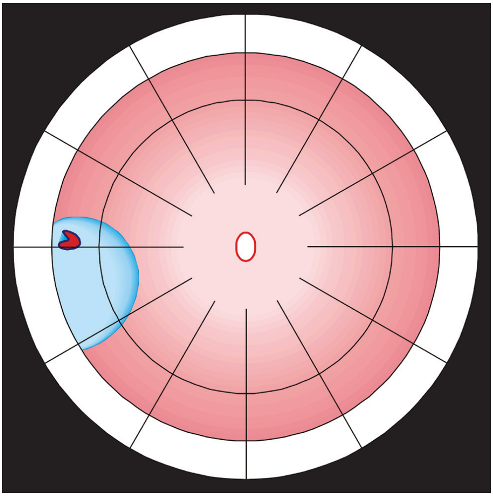
To reduce the surgical trauma of minimal segmental buckling without drainage even further, in 1979, Lincoff, Hahn, and Kreissig [36] replaced the segmental sponge sewed onto sclera by a temporary buckle. Subsequently the Lincoff-Kreissig balloon evolved (Fig. 6.9) [37, 38]. In contrast to the sponge buckle, (1) the application of the balloon buckle is limited to detachments with one break or a group of breaks within one clock hour, (2) the balloon is not fixated by sutures, and (3) it is withdrawn after 1 week. The rationales for removing the balloon after 1 week were the results of our earlier animal experiments on the strength of the cryosurgical adhesion and the time it takes to develop a sufficiently strong adhesion. Thus, 10 years after the experimental data on the strength of the cryosurgical retinal adhesion were obtained, it was confirmed by the temporary balloon buckle, placed under the break surrounded by cryosurgical lesions and removed after a week. The balloon operation is performed under topical or subconjunctival anesthesia.

No sutures have to be placed to fixate the balloon buckle, and the small conjunctival wound of 1–2 mm needed to insert the balloon catheter will close by itself after withdrawal of the balloon. After that, sustained attachment will depend exclusively on the strength of the retinal adhesion, induced by transconjunctival cryopexy prior to insertion of the balloon, or by laser, applied postoperatively, after attachment of the break on the balloon buckle.

The balloon operation represents the ultimate refinement of closing a leaking break ab externo and without leaving a buckle at the wall of the eye. The break is sealed off by surrounding retinal adhesions. It represents a procedure with a minimum of surgical trauma. The balloon operation follows the postulate of Gonin – to find the break and to limit the treatment to the area of the leaking break – and the principle of Custodis – not to drain subretinal fluid. With the balloon, the last complications of segmental buckling, infection or extrusion, and diplopia are eliminated.

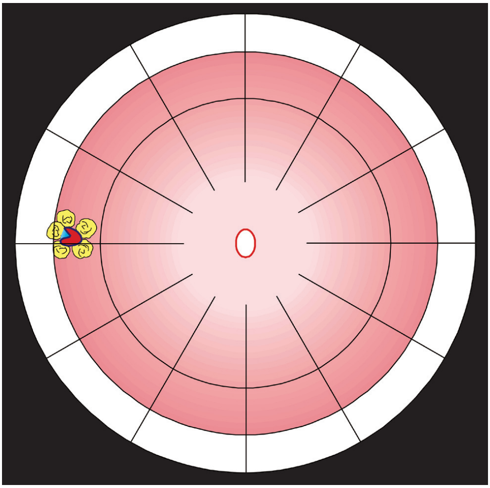
Some detachments, which were treated with the temporary balloon buckle, will be depicted:

1. A detachment with a break under a rectus muscle is an optimal indication (Fig. 6.10), since after withdrawal of the balloon, diplopia disappears.
2. A total pseudophakic detachment with an apparent circular anterior traction line (which is, in fact, the vitreous base), capsular remnants, and no certain break (Fig. 6.11). The treatment consists here as well of a temporary balloon buckle in the suspected area to test for the presence of a break; after attachment, the so-called traction line tends to disappear.



a

Fig. 6.10. Detachment with break under rectus muscle. **a** *Top:* The detachment has a break at 9:00 in the area of the rectus muscle. *Bottom:* With the parabulbar balloon placed in the area of the rectus muscle to tamponade the horseshoe tear at 9:00, the ocular rotations are limited



b

Fig. 6.10. b *Top:* After 1 week the balloon was withdrawn; after that only pigmented cryopexy lesions surrounding the horseshoe tear at 9:00 were visible. *Bottom:* Within hours after withdrawal of the balloon, the diplopia had disappeared, because the eye muscles function normally again

a

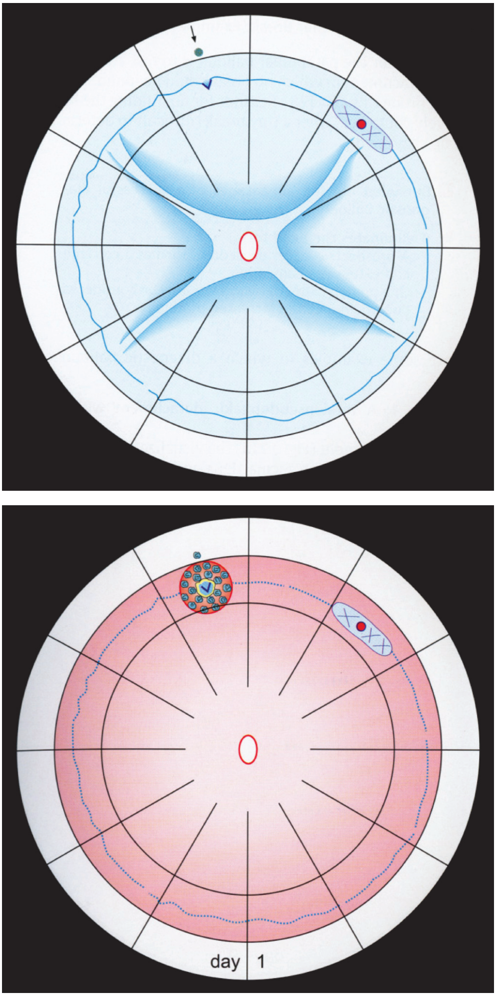


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Fig. 6.11a,b. Legend see page 117

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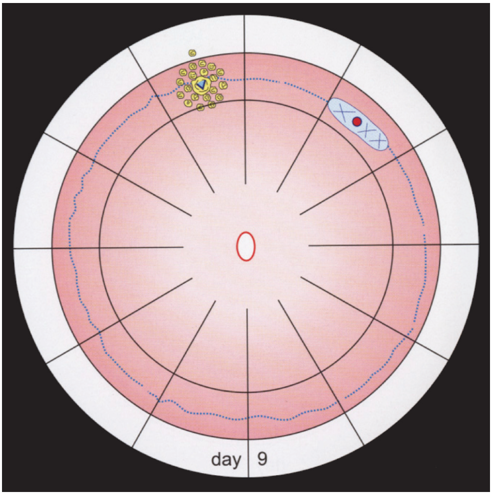


Fig. 6.11c

Fig. 6.11. A total pseudophakic detachment with capsular remnants. **a** In the detachment in the anterior so-called traction line at 11:30 a little tit was discovered. To find this area of suspicion at the operating table, in the radian of the tit a laser mark was placed in the pars plana prior to surgery. **b** After balloon operation (1 day): The balloon was inserted beneath the tit at 11:30. The localizing cryopexy lesion is visible on the balloon buckle. The retina is attached. Since a break was not found for certain, it has, however, to be located in the area of the balloon buckle. Therefore, the entire buckle had to be secured with interrupted laser lesions. The lattice degeneration with a pseudohole was not treated, not even at a later time. **c** After balloon operation at day 9: The balloon was withdrawn, and the entire area of suspicion, formerly placed on the buckle, is covered with pigmented thermal lesions. The retina remained attached during the entire follow-up of 7 years

3. An old detachment with a pigment demarcation line and an intraretinal cyst (Fig. 6.12); here too, a balloon buckle sufficed.
4. The balloon can also be used as a diagnostic tool to test for presence of only one break in two separate detachments (Fig. 6.13).
5. Or, the balloon can be used even in a detachment up for reoperation with PVR stage C2 (Fig. 6.14).

Why Is the Balloon Operation so Difficult to Accept?

The premises for success are: (1) a maximum of preoperative diagnostics, so as not to overlook a break; (2) a precise localization of the break at the table without prior drainage; (3) marking the detached break on mobile conjunctiva (in contrast to the segmental sponge operation, in which the break can be marked precisely on the sclera); and (4) localization of a highly elevated break on a yet slightly indenting parabulbar balloon in presence of a bullous detachment with a pronounced and misleading parallax.

Advantages of the Balloon Operation

Advantages of the balloon operation are as follows:

1. The surgery is short, ranging between 10 min and 20 min
2. The anesthesia is topical or subconjunctival
3. The recovery of vision is fast and optimal
4. The last complications of segmental buckling are eliminated, i.e., there is no buckle infection, because the balloon is removed, and no diplopia. Diplopia, if present, disappears after the balloon is withdrawn.

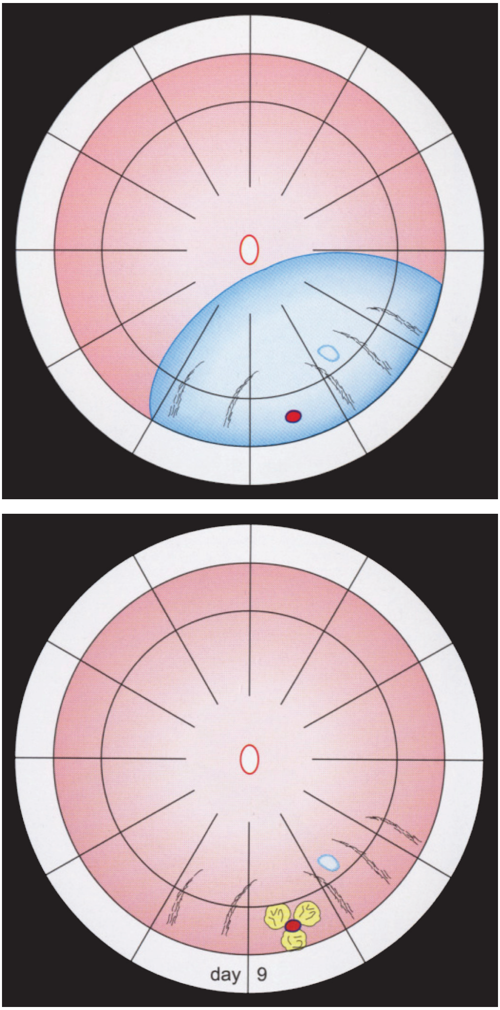


Fig. 6.12. Old inferior detachment. **a** The detachment has several pigment demarcation lines, an intraretinal cyst, and a round hole at 5:30. **b** After balloon operation at day 9: After balloon insertion (1 day) the retina had attached. After pigmentation of the cryopexy lesions around the break, the balloon was withdrawn after a week. There are still visible the pigment demarcation lines and the intraretinal cyst

Fig. 6.13. Two separate detachments with only one questionable break. **a** There is a superior detachment with two lattice degenerations and "erosions". A most likely break is located at 11:00 with obvious vitreous traction at the lateral edge of lattice degeneration. The convex pigment demarcation line beneath the superior detachment posterior to the lattice degeneration indicates that a full thickness break might be present at 11:00. In the inferior detachment, there is a questionable tear at 8:00 at the lateral edge of lattice degeneration. When lying the patient flat, no communication between the two separate detachments was detected. **b** After insertion of a diagnostic balloon (1 day) beneath the suspected break at 11:00: The break and the entire lattice is surrounded with cryopexy lesions. The superior retina had attached and the inferior detachment diminished in size, indicating that its fluid is originating from the superior break now being tamponaded. **c** After balloon operation (10 days): The balloon was withdrawn after 8 days when the cryopexy lesions were pigmented. The lattice degeneration at 12:00 was surrounded with laser lesions. There is still residual fluid around the inferior lattice degenerations. **d** After balloon operation (4 weeks): The residual fluid had disappeared. No further treatment was added

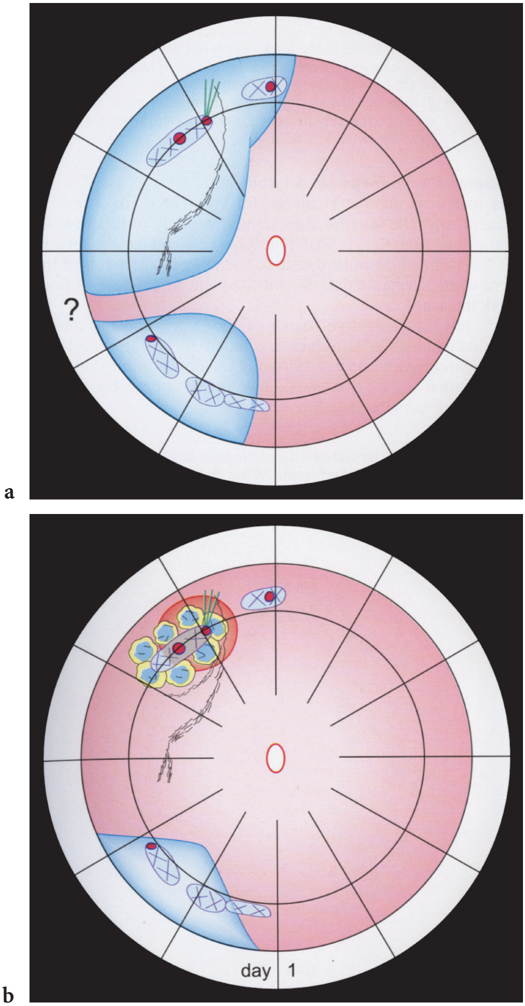
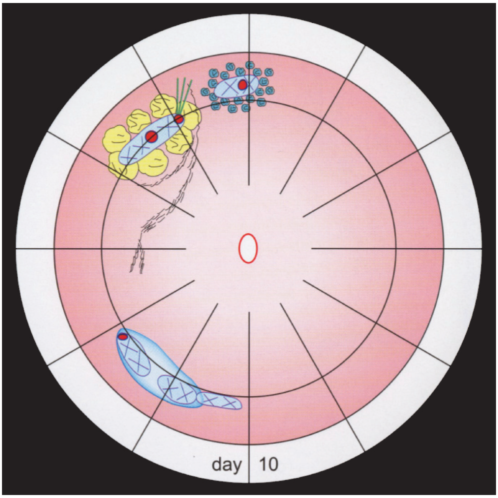


Fig. 6.13a,b. Legend see page 120



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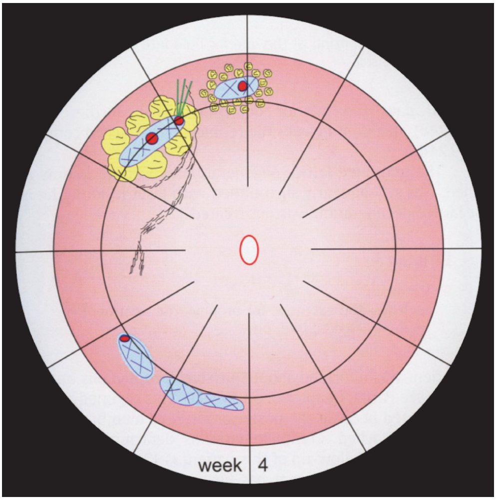

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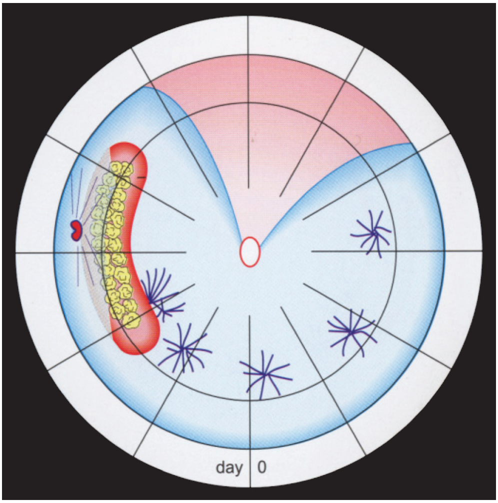
Fig. 6.13c,d. Legend see page 120



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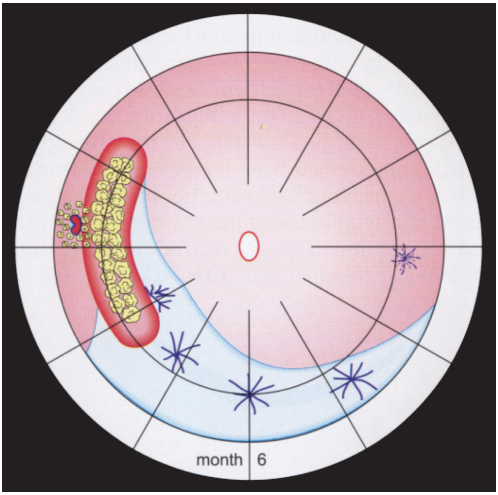

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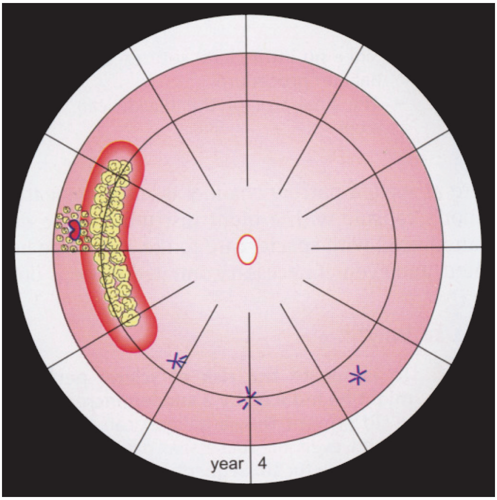
Fig. 6.14a,b. Legend see page 124



c

Fig. 6.14c

Fig. 6.14. Balloon as late reoperation of proliferative vitreoretinopathy (PVR)-C2 detachment. **a** A three-quadrant detachment with PVR and starfolds in two quadrants in an eye with a previous buckle operation with diathermy and a tear anterior to the buckle at 9:00. As minimal approach for reoperation in presence of diathermized sclera, a parabulbar balloon was selected. **b** After balloon operation (6 months): The macula had already attached 2 days after surgery. At 6 months, a residual traction detachment with concave contours and concave surface is persisting; the macula is still attached. **c** After balloon operation (4 years): The traction detachment has flattened, only faint remnants of starfolds are visible

All of the listed advantages can be achieved by applying a temporary and not suture-fixated balloon buckle without drainage as treatment for a primary retinal detachment. But the "conditio sine qua non" for success with this minimal procedure is experience in the non-drainage operation. The surgeon has to be an expert in indirect binocular ophthalmoscopy and has to be able to locate a balloon correctly in the parabulbar space beneath a highly detached break.

Minimal Segmental Buckling With Sponges or Balloons Without Drainage: A Medline Analysis

Materials and Methods

A Medline search was made of all reports that were identified by the search terms "retinal detachment," "segmental buckling," "minimal extraocular surgery," and "nondrainage." Reports published in English, German, Italian, French, Spanish, and in some East European journals were reviewed and analyzed. The majority of reports did not contain homogenous data suitable for the analysis. Many included both complicated and uncomplicated detachments, primary detachments and reoperations, or no preoperative characteristics. In many series, primary segmental buckling was combined with a cerclage. The buckling was performed with or without drainage of subretinal fluid. Primary segmental buckling was sometimes combined with an injection of air, an expanding gas, or silicone oil.

After excluding these reports, an analysis was made of a relatively homogenous series of mostly primary retinal detachments, some with preoperative PVR stage C1–C2. The primary procedure in all eyes was minimal segmental buckling without drainage of subretinal fluid. The analysis consists of five reported series with a combined total of 1,462 retinal detachments [26, 37, 39–42].

The preoperative characteristics of the 1,462 primary retinal detachments were: aphakia/pseudophakia in 8.3% and preoperative PVR stage C1–C2 in 2.9% (Table 6.1). All operations were done under local anesthesia. Coagulation was limited to the area of the break(s) and performed with intraoperative cryopexy under ophthalmoscopic control or with laser coagulation on a subsequent day after the break was attached. The buckle was limited to the area of the break(s) and was obtained with an elastic silicone sponge or a temporary balloon. Subretinal fluid was not drained in any eye. Some of the detachments treated are represented in Figs. 6.4–6.13, recruited from series 2 and 5. All patients were mobilized after

Table 6.1. Preoperative characteristics of 1,462 primary retinal detachments treated with minimal segmental buckling (sponges or balloons) without drainage

Series	Detachment	Aphakia pseudophakia	Perforating injury	Reoperation	Proliferative vitreoretinopathy stage		Myopia
					C1	C2	> −7 to −25 dpt
First [21, 39]	752	30	–	7	5	–	n.a.[a]
Second [26, 40]	107	22	–	–	12	4	9
Third [41]	35	3	–	–	5	1	5
Fourth [42]	68	5	1	–	11	–	5
Fifth [37][b]	500	62	3	30	3	2	71
		122 (8.3%)			43 (2.9%)		

[a] Not available
[b] Treated with balloon

surgery. The temporary balloon buckle was deflated and removed after 1 week.

Anatomical Results

Since subretinal fluid was not drained, complete disappearance of fluid in some eyes could take several days. Consequently, when applying minimal segmental buckling without drainage, one has to be able to differentiate between delayed absorption of subretinal fluid, residual tractional detachment, and surgical failure to avoid unnecessary reoperations.

The results after segmental sponges without drainage, applied in the first four series, were as follows: in the first series primary attachment was achieved in 672 eyes (89%), in the second in 99 eyes (93%), in the third in 35 eyes (100%), and in the fourth series in 65 eyes (96%). In the fifth series of 500 detachments treated with the temporary balloon buckle, the retina was attached and remained attached after removal of the balloon in 454 eyes or in 91% (Table 6.2).

Thus, after minimal segmental buckling, limited to the area of the break(s) and without drainage of subretinal fluid of 1,462

Table 6.2. Primary attachment after minimal segmental buckling (sponges or balloons) without drainage of 1,462 retinal detachments

Series	Detachment	Primary attachment
First [21, 39]	752	672 (89%)
Second [26, 40]	107	99 (93%)
Third [41]	35	35 (100%)
Fourth [42]	68	65 (96%)
Fifth [37][a]	500	454 (91%)
Total	1,462	1,325 (91%)

[a] Treated with balloon, attachment sustained after removal of balloon

Table 6.3. Final attachment after minimal segmental buckling (sponges or balloons) without drainage and reoperation of 1,462 primary retinal detachments during 2-year follow-up

Series	Detachment	Preoperative proliferative vitreoretinopathy C1–C2	Primary attachment	Reoperation	Final attachment	Cause of final failure		
						Proliferative vitreoretinopathy C1–C2	Missed break	Choroidal
First [21, 39]	752	5	672	60	732	14	4	3
Second [26, 40]	107	16	99	5	104	4	3	–
Third [41]	35	6	35	–	35	–	–	–
Fourth [42]	68	11	65	3	60	8	–	–
Fifth [37][a]	500	5	454	39	493	2	5	1
Total	1,462	43 (2.9%)	1,325 (91%)	107 (7.3%)	1,424 (97.4%)	28 (1.9%)	12 (0.8%)	4 (0.3%)

[a] Treated with balloon

detachments, primary retinal attachment was obtained in 1,325 eyes or in 91%. After reoperation, attachment resulted in 97.4% and persisted during a 2-year follow-up (Table 6.3).

Reasons for Primary and Final Failure

Missed Breaks

With minimal segmental buckling, if a break is missed and drainage not performed, the retina will not become attached at any time – not at the table, nor spontaneously in the days after surgery. A missed break was the cause of primary failure in 62 eyes or in 4.2% and, after reoperation, in 12 eyes or in 0.8% (Table 6.3).

Inadequate Buckles

The second most frequent cause of primary failure was an inadequate buckle, which was present in 51 eyes or in 3.5%. This was easily corrected by either moving the buckle or enlarging it. After reoperation, the buckle was no longer a reason for final failure.

Proliferative Vitreoretinopathy

Despite the fact that PVR stage C1–C2 was already present preoperatively in 43 eyes or in 2.9% of the 1,462 detachments treated, it was the cause of primary failure in only 20 eyes (1.4%) and, after reoperation, the cause of final failure in 28 eyes or in 1.9%.

Thus, the presence of PVR did not preclude applying minimal segmental buckling with sponges or balloons without drainage. By omitting drainage, a breakdown of the blood–aqueous barrier was eliminated. By performing cryopexy and buckling with a minimum of trauma to these vulnerable eyes, a progression of PVR could be circumvented.

Choroidals

In 4 of the 1,462 detachments, a postoperative choroidal effusion developed. These four eyes were highly myopic. Choroidals were the cause of primary failure and final failure in 0.3%. This is less than the reported 2% to 8.6% after cerclage with drainage [10].

Complications

Intraocular

Minimal extraocular surgery is performed without drainage of subretinal fluid. As a result, the intraocular complications of drainage, such as hemorrhage, intraocular infection, incarceration of retina or vitreous, do not occur. In addition, the need for a subsequent intraocular injection of gas or saline to restore intraocular pressure with its complications is also eliminated.

Secondary glaucoma, cataract, or anterior ischemia did not occur, and because the procedure was extraocular, there were no iatrogenic breaks. Intraocular complications from cryopexy did not occur, because all applications were monitored by indirect ophthalmoscopy for a medium lesion (first appearance of white in the retina) [43]. There was a rare choroidal in highly myopic eyes.

Extraocular

The extraocular complications that might occur with minimal segmental buckling without drainage are reversible. After using the Lincoff sponge-2 in 210 eyes (series 2 to 4), one sponge (<0.5%) had to be removed because of exposure: the retina remained attached after the sponge was removed. Diplopia did not occur because an effort was made to avoid trauma to the rectus muscles during the operation. If a break was localized in the area of a rectus muscle and a radial sponge intended, the muscle was split and re-sutured to either side of the sponge. When a very anterior circumferential buckle was needed, it was placed external to the muscle [44]. Most important were daily ocular motility exercises during the first postoperative week to counteract the development of adhesions around the muscle. This was done independent of the state of the retina. As a result, no sponge had to be removed because of diplopia.

In the fifth series (n=500), a temporary balloon buckle was applied, which was removed after 1 week. In this series, there was no buckle infection or exposure. Diplopia was sometimes present when the balloon was in place, but diplopia remitted in all eyes within hours after the balloon was removed.

Functional Results

Since the end of the 1960s, detachment surgery has been concentrating not only on anatomical results, but also on visual function [45–49] – both short-term recovery after surgery and long-term visual acuity.

In the first series, visual function was not described. In the remaining four series, treated with sponges or balloons, the mean visual acuity was 0.67 after 2 years (Table 6.4). The two questions that arise are: (1) Would visual acuity decline over years? (2) Would the presence of a segmental buckle over years cause a secondary deterioration of visual function?

These pending questions can be answered by the second series of 107 primary retinal detachments treated by minimal segmental sponge buckle(s) without drainage and with a complete follow-up of 15 years [40]. The mean preoperative visual acuity was 0.3; it improved to 0.5 during the first 6 months after surgery, and reached a maximum of 0.6 at 1 year. The increase was statistically significant ($P<0.001$). After 1 year, a slight linear decrease of 0.07 lines on the Snellen chart per year was observed over 15 years. In one patient, a cataract operation was done during the follow-up. The long-term functional results, including the surgical failures, are depicted in Fig. 6.15.

Table 6.4. Visual acuity at 2 years postoperatively after minimal segmental buckling (sponges or balloons) without drainage and reoperation of 1,462 primary detachments

Series	Detachment	Preoperative proliferative vitreoretinopathy C1–C2	Reoperation	Final attachment	Visual acuity 2 years postoperative
First [21, 39]	752	5	60	732	n.a.[a]
Second [26, 40]	107	16	5	104	0.6
Third [41]	35	6	–	35	0.6
Fourth [42]	68	11	3	60	0.3
Fifth [37][b]	500	5	39	493	0.7
Total	1,462	43 (2.9%)	107 (7.3%)	1,424 (97.4%)	0.67 (mean)

[a] Not available
[b] Treated with balloon

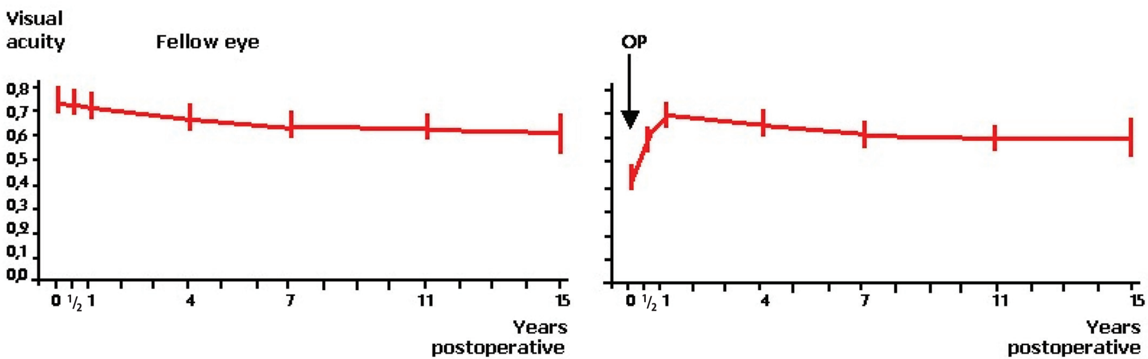


Fig. 6.15. Course of mean visual acuity of fellow and operated eyes during 15 years. *Left:* Course of mean visual acuity in the 107 *unoperated fellow eyes* during the 15-year follow-up. *Right:* Course of mean visual acuity in the 107 eyes with retinal detachment *operated with extraocular minimal surgery* (segmental sponge buckle(s) without drainage) during the 15 years after surgery. 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. Of the patients, 72 were alive 15 years after the operation. During the study period of 15 years, the difference in decrease of visual acuity was not significant between the unoperated fellow eyes and the operated eyes (with the segmental buckle(s) in place) at any interval

To analyze whether this slight decrease in visual function could be due to the presence of the segmental buckle or to secondary complications, the visual acuity of the fellow eyes was compared with the operated eyes at all intervals. There was no significant difference ($P=0.079$) in visual acuity over the 15 years. In this context, the data of Slataper are of value [50]. He had plotted the visual acuity of 17,349 individuals as a function of age and found that after the age of 60, a linear decrease of 0.07 lines per year on the Snellen chart occurs and that this decrease is age-dependent. There is no statistically significant difference between the observed decrease over the years, determined by Slataper, and the one in the analyzed operated eyes.

Thus, postoperative visual acuity (even when including the surgical failures) with a maximum of 0.6 at 1 year after surgery had only slightly decreased to 0.5 during 15 years. There was no statistically significant difference from the course in the fellow eyes over the ensuing 15 years; it was due to aging.

Series 2 through 5, with a combined total of 710 retinal detachments treated with segmental sponges or balloons without drainage, provide useful data on postoperative visual acuity and its course over 2 years (Table 6.4) to 15 years (Fig. 6.15). The long-term postoperative visual acuity of the eyes treated with sewed-on buckles, limited to short segmental sponges to close the retinal breaks, confirm that minimal segmental buckling has no negative effect on long-term visual function.

Disadvantages of Primary Minimal Segmental Buckling Without Drainage

Disadvantages of primary minimal segmental buckling without drainage are as follows:

1. Preparation for a minimal buckle operation, limited to the break and without drainage, requires extensive preoperative

study. When a retinal break is not obvious, intensive biomicroscopic study of the peripheral retina can be time-consuming, but is necessary.

2. A prerequisite for minimal segmental buckling without drainage is having experience in indirect ophthalmoscopy and biomicroscopy to be able to find all of the breaks.
3. Experience with the special guidelines (the 8 Rules) and indirect wide-field contact lenses can help the biomicroscopic search for small breaks in a pseudophakic eye [19, 20–22, 51].
4. There is a learning curve to localizing posterior breaks in a bullous detachment and buckling them adequately without drainage of subretinal fluid.
5. If a radial sponge is placed in the area of a rectus muscle, diplopia may occur. But diplopia can be averted with the use of a temporary balloon for breaks located beneath a rectus muscle.
6. Exposure or infection of the sponge buckle can occur, but is infrequent and ranges at <0.5%. After removal of the sponge, redetachment is rare, if a week or more has elapsed and the coagulation-induced adhesions have matured. In some cases, supplemental laser around the break may be applied prior to removal of the buckle.
7. The concept of minimal buckling without drainage can be difficult to accept because the retina is not attached at the operating table. Instead, the surgeon must wait for 24 hours or more for the retina to attach spontaneously. This may be a strain on the surgeon and "disturb his sleep," as often described. However, postoperative spontaneous attachment is an absolute confirmation that the operation was correct.

Advantages of Primary Minimal Segmental Buckling Without Drainage

Advantages of primary minimal segmental buckling without drainage are as follows:

1. The procedure is extraocular.
2. It is performed under local or topical anesthesia.
3. It can be done in an outpatient setting.
4. It can be performed on a low budget, because it uses less operating time (rarely more than 45 min and 10–20 min with the balloon), inexpensive equipment, and few trained personnel in attendance. For the surgery itself, no costly disposable instruments or expensive intraocular tamponades are required.
5. It can be applied for superior and inferior breaks.
6. There are, except for a rare choroidal in 0.3%, no intraocular complications, such as: secondary glaucoma, cataract, intraocular hemorrhage, intraocular infection, incarceration of retina or vitreous, or iatrogenic tears, because the procedure is extraocular.
7. No postoperative head positioning of the patient is required during the day or at night while asleep, and traveling by airplane is not restricted because intraocular gas is not injected.
8. The primary attachment rate of 1,462 primary retinal detachments treated with minimal segmental buckling and without drainage is 91% and after reoperation 97.4% over 2-year follow-up.
9. The low rate of redetachment: over a 2-year follow-up the rate of redetachment in the 1,462 eyes treated with minimal segmental buckling averages 0.6% per year (series 1 to 5) and over a follow-up between 2 years and 15 years (series 2) 0.5% per year.
10. The recovery of visual acuity is optimal after minimal segmental buckling without drainage. In the series of 107 detachments with a mean preoperative visual acuity of 0.3, the mean value at 1 year is 0.6 and 0.5 at 15 years. The observed slight decrease over years is an effect of aging and not of secondary complications.
11. This low rate of intraoperative and postoperative complications, combined with optimal long-term visual results, is of benefit to the elderly patient and to the decreasing financial resources. This becomes more relevant because new treatments for various

macular and retinal diseases are increasingly available, however, at very high costs.

Discussion

In recent publications, the results of primary vitrectomy have been compared with the results obtained with scleral buckling. However, the comparison was done with scleral buckling consisting of a cerclage with extensive coagulations, with drainage of subretinal fluid, and, frequently, with an intraocular gas tamponade. With that comparison, it was concluded that scleral buckling has a higher morbidity than primary vitrectomy [52–54]. Yet, had they compared primary vitrectomy with minimal segmental buckling without drainage, they would have concluded that segmental buckling without drainage has less morbidity than primary vitrectomy [55].

Despite the excellent results that can be obtained with the minimal buckling technique, vitrectomy as a primary procedure is increasingly used. This is the case even though a recent analysis of 595 detachments treated with vitrectomy, performed by experts, found that the rate of reoperation was 24.5% and PVR 11.5% [56] in contrast to minimal segmental buckling with a rate of reoperation at 7.3% and PVR at 1.9% (Table 6.3).

Retinal breaks, even small breaks, should be found preoperatively. Postponing the search to the time of surgery should be a last resort. Parenthetically, detecting breaks preoperatively is less costly because the search uses only the time of the surgeon; a search for breaks during surgery uses the time of additional personnel in attendance in an expensively equipped operating room.

It is of interest that failing to close the break is still the main cause of failure, regardless of the procedure employed. A recent publication about 171 primary detachments treated with a primary vitrectomy [57] demonstrated that the reason for primary failure was a missed or leaking break in 64.3% of failures. In comparison, the causes of the 91 primary failures after 962 sponge buckles

Table 6.5. Reasons of primary failure (n=91) after one operation with minimal segmental sponge buckle(s) without drainage of 962 primary retinal detachments

Series	Detachment	Cause of primary failure				Total
		Missed break	Inadequate buckle	PVR	Choroidals	
First [21, 39]	752	31+2[a]	27	17	3	80
Second [26, 40]	107	4	4	–	–	8
Third [41]	35	–	–	–	–	–
Fourth [42]	68	2	1	–	–	3
Total	962	39	32	17	3	91
		71 (78%)				

[a] Macular hole

(series 1–4) was 39 times a missed break and 32 times an inadequate buckle. Thus, failure to close the leaking break accounted for 71 of 91 failures or 78% (Table 6.5).

Thus, a leaking break still remains the main cause of primary failure, and vitrectomy has not significantly altered this. This validates the postulate of Gonin, defined more than 70 years ago: the retinal break causes the detachment.

However, in the future, the requirements of an optimal surgery for repair of a primary retinal detachment might be more specific:

1. Just *one* operation should attach the retina once and for all
2. The surgery should have a *minimum of morbidity*
3. The procedure should be done on a *small budget* and under *local anesthesia*

4. The operation should provide a *maximum of long-term visual function, not jeopardized* by secondary complications during the prolonged life expectancy of the patient treated

Outlook

Minimal segmental buckling by a sponge or a balloon and without drainage of subretinal fluid is the ultimate development of scleral buckling introduced by Schepens and Custodis and subsequently refined by Lincoff, Kreissig, and others. Minimal segmental buckling without drainage provides an optimum of early and late anatomical and visual results: retinal attachment results after one operation in 91% and after reoperation in 97%. However, to obtain this rate of attachment requires an expertise in biomicroscopy and binocular indirect ophthalmoscopy to find the breaks preoperatively and at surgery to localize these breaks correctly and to adequately position the segmental buckle beneath them without drainage of subretinal fluid. However, this "Art of minimal segmental buckling" [25, 26] has a learning curve.

Detachments in pseudophakic eyes today are almost routinely assigned to vitrectomy for primary repair. This may occur even when the break can be visualized preoperatively and would respond to a segmental buckle without drainage. For these eyes in which the break cannot be found because the peripheral retina is obscured by a narrow pupil or capsule opacities, a vitrectomy to provide better access for viewing the anterior retina may provide a better prognosis than prospective buckling, being based on the contour of the detachment, or a cerclage.

However, we have to keep in mind that the resources available for ophthalmology are diminishing as life expectancy increases and new treatments for various macular and retinal diseases become available. This expanding spectrum includes invasive and noninvasive, but expensive, treatment modalities. All this may force us to reconsider how to spend the limited resources for the increasing number of patients.

Probably, the future question no longer will be: which method is better for attaching a primary detachment:

1. A limited or a prospective buckle?
2. An intraocular or extraocular surgery?

Rather, it will be:

3. Which method is applied at its optimum with a minimum of strain on our financial resources?

And this could mean treating a break in a primary detachment by an extraocular surgery, limited to the break, i.e., a surgery, performed under local anesthesia and on a small budget, with a low rate of morbidity and reoperations, and with optimal long-term visual results. Perhaps in the future a less morbid procedure to attach the retina will be developed, or the pendulum of detachment surgery, as witnessed already during the past 75 years, might swing back to an extraocular minimal surgery. And in this case, we again might have to train surgeons skilled in preoperative diagnostics to find the break(s) and in the art of applying a minimum of segmental buckling without drainage to attach a retina.

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Pharmacological Approaches to Improve Surgical Outcomes After Retinal Reattachment Surgery

Mark S. Blumenkranz

Introduction

Prior to the modern era ushered in by Gonin, with the recognition that retinal detachment is caused by retinal breaks, a variety of nonspecific and pharmacological methods were employed, without predictable success, for the treatment of retinal detachment. It remains true today that the most important pharmacological agent in the diagnosis and treatment of retinal detachment is the mydriatic drop, since without adequate visualization of the fundus and identification of the break, no definitive treatment is possible. Other opportunities still exist for the pharmacological enhancement of retinal reattachment, by improvement in both anatomical and functional results. These include (1) improvement in the final retinal reattachment rate, (2) improvement in visual acuity following successful retinal reattachment, and (3) reduction in complications.

Inasmuch as the majority of routine or uncomplicated retinal detachments can now be accomplished safely by utilizing modern scleral buckling techniques, the risk–benefit ratio of utilizing potentially toxic pharmacological agents under routine circumstances has to be carefully considered in light of the opportunities for marginal potential improvement [1]. However, given the increasing utilization of pneumatic retinopexy, which seems to have a lower initial retinal reattachment rate than conventional scleral buckling [2], the justification for the use of pharmacological agents may be increased. Some authors now propose primary vitrectomy without scleral buckling as a first operation, and although the immediate postoperative morbidity may be lower, the final rate of proliferative vitreoretinopathy (PVR) may be higher than scleral buckling alone [3–5]. Similarly, when scleral buckling alone is considered for eyes with early or late forms of proliferative vitreoretinopathy, success rates are considerably lower, and the case for use of an adjuvant agent, either to facilitate intraoperative flattening, such as perfluorocarbon, or one of several different anti-proliferative agents seems better justified [7–9]. Recently, a British group has developed a predictive formula to calculate the risk of PVR following primary retinal reattachment, which may aid in the selection of patients who might benefit most from the use of adjuvant pharmacological methods [10].

Improvement in Visual Acuity

Improvements in visual acuity following reattachment surgery may be achievable using several different methods. The first would be a reduction in the rate of complications associated with macular dysfunction. These include both macular edema and macular pucker. Both are well-described complications of retinal reattachment surgery as well as other vitreoretinal conditions and may be amenable to pharmacological intervention. Recent reports suggest that intravitreal steroids, principally triamcinolone acetonide, and also dexamethasone in a bioerodable polymer may reduce macular edema associated with several conditions, including diabetic retinopathy, uveitis, and retinal vein occlusion [11, 12]. The use of steroids by other routes of administration, including oral and parenteral, may also be of benefit in preventing macular complications, such as pucker [13].

It may also be possible to improve visual acuity through the enhancement of photoreceptor regeneration in eyes with macula-off retinal detachments. Processes governing photoreceptor renewal and normal alignment of the outer segments following retinal reattachment are still poorly understood, and the potential use of pharmacological agents and, specifically, cytokines may be a promising avenue to restoring visual function above and beyond that which might be expected simply by reattachment of the macula, particularly in eyes with more longstanding retinal detachments. To date, there are no well-defined or well-controlled clinical trials that would suggest such an agent is available or on the near horizon, but it is anticipated that in the future this approach may be feasible.

Reduction in Other Non-Macular Complications Limiting Either Anatomic Retinal Reattachment or Normal Physiological Function

Well-known complications of retinal reattachment surgery include alterations in the intraocular pressure, both glaucoma and hypotony, postoperative inflammation, cataract, motility disorders, and PVR. Pharmacological therapy, both intraoperatively as well as postoperatively, may play a role in the reduction of several of these complications, either singly or in combination. The remainder of this chapter is devoted to a discussion of the principal cause of retinal reattachment failure after primary surgery, PVR, and the methods by which pharmacological therapy might favorably influence this condition.

The Cell Biology of PVR

PVR is the most common cause of failure following attempted retinal reattachment repair in primary cases, as well as complex forms of retinal detachment. The precise initiating events remain poorly understood, but it is known that the disease is characterized by cell-mediated tractional forces exerted on both preretinal and subretinal membranes, as well as more diffusely to the vitreous gel itself [9,14,15]. These contractile forces lead to stiffening and elevation of the retina, leakage through retinal breaks, and retinal redetachment typically between 4 weeks and 8 weeks following attempted repair. The condition is more commonly encountered in eyes with large or multiple breaks and is more frequently seen in males and in patients with a history of trauma, hemorrhage, choroidal detachment, or giant retinal tear [5,10]. The membranes associated with this condition are composed of a variety of cell types, principally pigment epithelial, glial and myofibroblastic elements, either interspersed within the gel producing compaction of the collagen (hypocellular gel contraction) [15] or defined hypercellular membranes on either the anterior or posterior surface of the retina [14]. Two of the earliest findings in eyes that go on to develop PVR are breakdown of the blood–ocular barriers with increased amounts of intravitreal protein and free-floating dispersed cells, principally retinal pigment epithelium (RPE). The cells appear to enter the growth cycle and actively proliferate in response to chemotactic and mitogenic stimuli and, subsequently, undergo an orderly sequence of steps, including attachment, contraction, and secretion of newly formed extracellular matrix (ECM) [14–21].

Initially, attempts to treat this condition by scleral buckling techniques alone were largely unsuccessful, as were the earliest techniques using vitrectomy without supplemental long-acting tamponades [6, 7, 14]. These initially unsuccessful surgical approaches served as the principal stimulus for a search for antiproliferative agents that might improve success rates. Early studies were performed using triamcinolone acetonide, daunomycin, and fluorouracil in the early 1980s prior to the widespread availability of long-acting gases and silicone oil [8, 22–26].

The introduction of long-acting gases, particularly perfluoropropane, and the re-emergence of silicone oil (polydimethylsiloxane) were major steps in the improvement in surgical success rates. The definitive silicone oil study confirmed that while silicone oil was superior to sulfur hexafluoride in providing visual acuity improvement and retinal reattachment in PVR, a companion study further amplified the relative equivalence of perfluoropropane to silicone oil in achieving retinal reattachment [27]. Approximately 64–73% of patients in the latter study achieved complete posterior retinal attachment and 43–45% achieved functional visual acuity of greater than 5/200 compared with success rates less than half that prior to the utilization of both of these long-acting tamponade techniques [28]. Paradoxically, with the improvement in anatomic reattachment associated with the long-acting tamponades of perfluoropropane and silicone oil, both the medical need and the likelihood of demonstrating a statistically significant treatment benefit by incremental pharmacological methods were reduced, although studies actively continued throughout the 1980s and early 1990s to develop new pharmacological therapies. In addition to reducing the driving force for development of new drugs due to improved surgical success rates, the use of long-acting tamponades, including silicone oils and long-acting gases, also created unique problems related to bio-availability because of the presence of either a gas-filled eye or an eye filled with an hydrophobic agent [29]. Additionally, subsequent to the publication of the results of the silicone oil study, another pharmaceutical compound used as a temporary intraoperative tamponade, perfluoro-*n*-octane, as well as other liquid perfluorochemicals came into common use. The use of these compounds further improved the success rates for complex forms of retinal detachment repair in conjunction with long-acting tamponade even without the use of other pharmacological anti-proliferative agents with success rates reported in the range of 78% [30].

The General Approach to Pharmacological Therapy

The search for drugs to inhibit vitreoretinal scarring either preceding or following retinal reattachment surgery has proceeded along lines that target the specific steps of the vitreoretinal scarring response, including cellular activation, proliferation, ECM elaboration, and contraction. This process has been facilitated by the use of cell-culture methods for initial screening [31, 32]. Some drugs attack specific points within the cycle, whereas other agents may attack more than one, such as steroids or heparin-like compounds. The various agents have been divided into classes according to their mechanism of action. These include the following: (1) anti-inflammatory agents, (2) drugs that inhibit cellular proliferation, (3) drugs that act on the ECM and cell surface. A general review of these classes of drugs follows.

Anti-Inflammatory Agents

Corticosteroids were the first agents to be employed in the treatment of experimental PVR and have recently regained currency based upon their widely disparate effects [24]. It is known that steroids exhibit a bimodal effect on cultured fibroblasts, causing stimulation at low doses and inhibition at supraphysiological doses [31]. Triamcinolone acetonide has been shown to reduce experimental PVR in a rabbit model after the injection of cultured fibroblasts [24]. One human clinical study employing oral prednisone showed a reduced rate of macular pucker, a limited form of proliferative response, after retinal reattachment surgery, although it did not affect the ultimate reattachment rate or rate of PVR [13]. Intravitreal steroids, when included in the infusate with heparin, resulted in a lower rate of retinal reoperation in one clinical study [33]. A novel use of intravitreal triamcinolone recently described by Peyman and colleagues involves visualizing remnants of the residual vitreous cortex following injection of a suspension of triamcinolone acetonide and, thereby, enhancing a full removal of cortex and vitreous membranes in a more expeditious manner [34].

Drugs That Inhibit Cellular Proliferation

A variety of subclasses of anti-proliferative agents have been shown to be effective in animal models as well as more recently in clinical trials. The greatest clinical experience has been obtained with fluoropyrimidines [8, 22, 23, 28, 29, 31, 35–42]. Fluoropyrimidines were first chosen because of their potency in inhibiting cellular proliferation in vitro compared with a relative lack of toxicity at high concentrations in toxicological studies [8, 31]. 5-Fluorouracil, the first agent to be tested in detail, has been found to have a median inhibitory dose (ID 50) of between 0.35 μg/ml and 0.71 μg/ml for most ocular and vascular cell types tested [31]. 5-FU has been found to be non-toxic as an intravitreal injection and can be well tolerated both in animals and in humans following intravitreal injections of up to 1.0 mg [8]. The drug is thought to exert its effect by enzymatic conversion into the ribose nucleotide form, which in turn both effects protein synthesis and also the enzyme thymidylate synthetase. Other fluoropyrimidine cogeners, particularly the ribonucleoside (5 FUR), have not only anti-proliferative effects like 5-FU, but also anti-contractile effects, which 5-FU does not seem to exhibit, at least in culture. These, however, are associated with a greater potential toxicity than 5-FU [31, 32, 39].

One of the theoretical problems associated with drug therapy employing 5-FU in eyes undergoing surgery for PVR is interaction with the long-acting tamponade, whether it is gas or silicone oil. In one study, a sustained release of a co-drug of 5-FU and fluocinolone pellet was tested in gas-filled eyes and found to be effective in releasing drugs in a manner comparable with non-gas-filled eyes [40, 41]. Co-drugs of 5-FU linked to an alkyl side-chain are soluble in silicone oil, whereas 5-FU itself is not and may be slowly released into the vitreous cavity by hydrolysis of the alkyl side-chain and 5-FU bond. To date, no studies have been performed on humans employing this technique, although it retains some promise [29].

The first randomized prospective clinical trial testing the efficacy of intravitreal 5-FU combined with low-molecular-weight heparin was published in eyes undergoing retinal reattachment and thought to be at high risk for the development of PVR rather than having already established PVR. In this study, 200 µg/ml of 5-FU and 5 IU/ml of low-molecular-weight heparin were added to the intravitreal infusate in a randomized fashion, with the remainder of the patients receiving a placebo injection into the infusate during vitrectomy. The incidence of post-operative PVR was judged to be lower at 6 months in the treatment group (12.6%) than the placebo group (26.4%), with those in the placebo group also requiring a higher re-operation rate than those in the 5-FU group. However, no differences were seen in the final complication rates [42]. Results of a similar protocol for the treatment of established PVR are still pending at the time of writing of this chapter.

Daunomycin

Another anti-proliferative agent, daunomycin, has been tested in preclinical and clinical studies. The drug is an anthracycline antibiotic with efficacy in an animal model. Daunomycins appear to have a somewhat lower therapeutic index than 5-FU, principally due to its greater toxicity; but it has been tolerated in animals and in humans as a continuous intravitreal infusion of 7.5 µg/ml for 10 min. In pilot studies of patients undergoing vitrectomy, daunomycin was felt to be effective [26, 43]. A variety of other agents have been employed for the treatment of experimental PVR, with no significant published data yet in human trials. These include retinoids, which play an important role in the differentiation and proliferation of various cell types, including RPE. The treatment of RPE cells with vitamin A (all-trans-retinol) significantly inhibits cellular proliferation migration in vitro as well as having effects on morphology [44]. Immunotoxins composed of a monoclonal antibody linked to a biological toxin have been employed in experimental models, including an antibody against the human transferrin receptors to the A chain of ricin [45].

Another chemotherapeutic agent useful in cancer and also in the treatment of coronary restenosis, Taxol, has been tested for efficacy in experimental models in the eye. It appears to act as a promoter rather than an inhibitor of microtubular assembly and inhibits cell-mediated contraction of a collagen gel as well as experimental retinal detachment in various animal models [46]. A related cytoskeletal agent, Colchicine, also inhibits RPE astrocyte and fibroblast proliferation in addition to migration and was shown in one animal model to have some beneficial effects on PVR, although it has not yet been proven to be beneficial in any human studies [47].

Drugs Acting on the ECM

Drugs which act on the interface between cells and the ECM have the potential to inhibit intraretinal scarring at a relatively earlier step than simple proliferation. Heparin and related peptides have a multitude of effects on cells and their interaction with the ECM. Heparin is a glycosaminoglycan derived from heparin sulfate, which binds to several ECM proteins, including fibronectin, laminin, and vitronectin [48]. In addition to its antithrombotic properties, for which it was first discovered and processed, heparin clearly has important effects on a variety of growth factors. It actively binds fibroblast growth factor, platelet-derived growth factor, and endothelial-cell growth factor. Soluble heparin causes an increase in cell spreading and produces changes in the cytoskeleton of smooth muscles. It also inhibits the polymerization of type-1 collagen and reduces cell-mediated contraction of collagen gels when cultured fibroblasts or RPE cells are interspersed within a collagen matrix. This may be a process analogous to hypocellular gel contraction, an important attack point in the prevention of PVR [15, 48].

Because heparins have significant anticoagulant affects, they may result in hemorrhagic complications, and this stimulated the search for compounds with heparin-like qualities on growth factors, but without the potential hemorrhagic issues. It is known that fractionation of longer chains of heparin into smaller molecular weight fragments causes loss of some of the anticoagulant activity while preserving the ECM effects. As a result, low-molecular-weight fractions of heparin with a molecular weight of 5000 or less retain their ability to catalyze the inhibition of Factor Xa, but lose their ability to directly inhibit thrombin [49]. When low-molecular-weight heparin was introduced into the infusate during vitrectomy in an animal model, fibrin formation was markedly reduced without any coincident increase in intraocular hemorrhage [50]. Use of 5 IU/ml of low-molecular-weight heparin in the infusate during creation of an experimental model of proliferative vitreoretinopathy reduced the rate of traction detachment from 77% to 28% at 3 months [51]. These encouraging results led to the inclusion of low-molecular-weight heparin in the infusate, along with 5-FU, which was studied in the prevention of PVR in humans [15, 42, 50, 51].

In another important PVR trial, when conventional heparin (1 IU/ml) was combined with a steroid dexamethasone (5 mg/ml) in the infusate, there was a slight increase in the retinal reattachment rate compared with controls from 65% to 80% in addition to a reduction in the rate of reproliferation from 26.5% to 16%. A mild increase in the rate of hyphema and vitreous hemorrhage was seen, although it was not judged to be clinically significant [33].

Summary

Pharmacological methods remain a promising potential adjunct to the successful treatment of retinal detachment. In addition to conventional strategies, including adequate pupillary dilatation, control of inflammation by anti-inflammatory agents, and intraocular pressure by ocular hypotensive agents, drugs may play a further role by inhibiting other late complications. These include proliferation and macular edema. Steroids, fluoropyrimidines, and heparin-like compounds, particularly low-molecular-weight heparin, all appear to be potentially useful agents either singly, or in combination. The ability to combine agents together with differing mechanisms of action, either as a single intravitreal injection, or, more recently, as a component of the infusate or with extended delivery devices, opens up new therapeutic avenues. Issues related to bioavailability, particularly in eyes with long-acting tamponades, either gas or silicone oil, are particularly challenging but intriguing. The use of modern bioerodable polymers and other fixed extended delivery devices may further enhance the utilization of such agents. In the future, additional capabilities, including the use of intravitreal steroids for control of macular edema and cytokines for the improvement of photoreceptor recovery, may further improve visual acuity results beyond those that might be expected when anatomic reattachment reaches a high plateau. Further understanding of the cellular biology of retinal reattachment and macular function will undoubtedly lead to concomitant improvements in therapeutic advances.

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Systematic Review of Efficacy and Safety of Surgery for Primary Retinal Detachment

Harvey Lincoff, Anne Lincoff, Marcin Stopa

Introduction

There is currently a debate about whether the buckle operation should be replaced by two intraocular procedures, pneumatic retinopexy and vitrectomy, for the repair of retinal detachment. To obtain comparative results, we examined case series in the literature from 1972 to 2003 that enrolled patients with primary retinal detachment who were treated by either pneumatic retinopexy, vitrectomy, or segmental buckling.

Materials and Methods

The literature was reviewed from 1972 to 2003 for reports about repair of primary retinal detachment. The database (Medline) was searched with keywords: primary retinal detachment and pneumatic retinopexy, vitrectomy, and buckle. We found a total of 329 trials (Tables 8.1–8.3). Inclusion criteria were that the detachments were uncomplicated; the extension of the detachments, number of breaks, and the age of the detachments were not a factor. Studies were excluded if proliferative vitreoretinopathy (PVR) was greater than a C1. There were 25 studies enrolling 1,465 patients treated with primary vitrectomy [1–25], 29 studies enrolling 1,919 patients for pneumatic retinopexy [26–54], and 10 studies enrolling 1,854 patients treated with segmental buckles [55–62]. Unsuccessful primary attachment and the presence of PVR postoperatively were

Table 8.1. Pneumatic retinopexy studies

Study	Year	Number of patients (total 1919)	Second surgery (total 484)	Proliferative vitreoretinopathy (total 111)
Kleinmann [26]	2002	44	20%	7%
Abecia [29]	2000	219	18%	3%
Eter [27]	2000	78	35%	6%
Assi [28]	1999	31	39%	13%
Lisle [30]	1999	36	17%	3%
Han	1998	50	36%	12%
Tornambe [54]	1997	302	32%	10%
Mulvihill [32]	1996	10	10%	n. a.[a]
Grizzard [33]	1995	107	31%	n. a.[a]
Gunduz [34]	1994	30	10%	3%
Boeker [35]	1994	133	27%	5%
Sebag [36]	1993	45	13%	2%
Bochow [37]	1992	17	29%	12%
Algvere [44]	1992	51	14%	4%
Berrod [39]	1990	56	34%	16%
Tornambe [31]	1989	103	27%	7%
Termote [40]	1989	20	20%	5%
Lemmen [41]	1989	54	50%	6%
Skoog [42]	1989	50	16%	n. a.[a]
Lowe [43]	1988	55	18%	n. a.[a]
Algvere [38]	1988	58	36%	14%
McAllister [45]	1988	56	29%	7%
Chen [46]	1988	51	37%	4%
Hilton [50]	1987	100	16%	6%
Poliner [48]	1987	13	31%	8%
Gnad [49]	1987	27	4%	0%
van Effenterre [24]	1987	60	10%	2%
Hilton [47]	1986	20	10%	5%
Dominguez [51]	1986	43	7%	2%
Weighted average			25.2%	6.5%

[a] Not available

Table 8.2. Vitrectomy studies

Study	Year	Number of patients (total 1465)	Second surgery (total 196)	Proliferative vitreoretino-pathy (total 76)
Pournaras [2]	2003	51	4%	2%
Tanner [3]	2001	9	11%	n. a.[a]
Oshima [1]	2000	47	9%	4%
Miki [4]	2000	87	8%	1%
Speicher [5]	2000	78	6%	5%
Pournaras [6]	2000	76	3%	1%
Gastaud [7]	2000	19	16%	n. a.[a]
Brazitikos [13]	2000	103	6%	4%
Oshima [9]	1999	63	8%	0%
Newman [10]	1999	25	16%	8%
Devenyi [11]	1999	94	0%	0%
Campo [12]	1999	275	12%	6%
Brazitikos [8]	1999	14	0%	0%
Sharma [14]	1998	21	10%	10%
Hoerauf [15]	1998	37	14%	8%
Desai [16]	1997	10	0%	n. a.[a]
El-Asrar [17]	1997	22	0%	5%
Yang [18]	1997	10	10%	n. a.[a]
Heimann [19]	1996	53	36%	6%
Bartz-Schmidt [20]	1996	33	6%	3%
Hoing [21]	1995	32	22%	19%
Girard [22]	1995	103	26%	17%
Gartry [23]	1993	114	26%	8%
van Effenterre [24]	1987	60	13%	0%
Escoffery [25]	1985	29	21%	7%
Weighted average			13.3%	5.3%

[a] Not available

Table 8.3. Scleral buckle and balloon studies

Study	Year	Number of patients (total 1854)	Second surgery (total 170)	Proliferative vitreoretinopathy (total 17)
Oshima [1]	2000	55	9%	4%
Green [61]	1996	162	12%	2%
Kreissig [62]	1992	107	7%	4%
Kreissig [56]	1989	500	7%	0%
McAllister [45]	1988	28	36%	7%
Richard [60]	1987	100	6%	n. a.[a]
Binder [58]	1986	52	4%	n. a.[a]
Schoch [59]	1986	45	7%	2%
O'Connor [55]	1976	50	0%	0%
Lincoff [57, 67]	1972	755	11%	0%
Weighted average			9.1%	0.9%

[a] Not available

the main outcome measures. Patient and surgical characteristics were mostly homogeneous. The common denominator was that the detachment might have responded to scleral buckling.

Results

The pooled risk of second surgery for primary vitrectomy was 13.3% (196/1,465), for pneumatic retinopexy 25.2% (484/1,919), and for segmental buckling 9.1% (170/1,854). The pooled risk of PVR after vitrectomy was 5.3% (76/1,417), after pneumatic retinopexy was 6.5% (111/1,697), and after scleral buckling 0.9% (17/1,702) (Fig. 8.1).

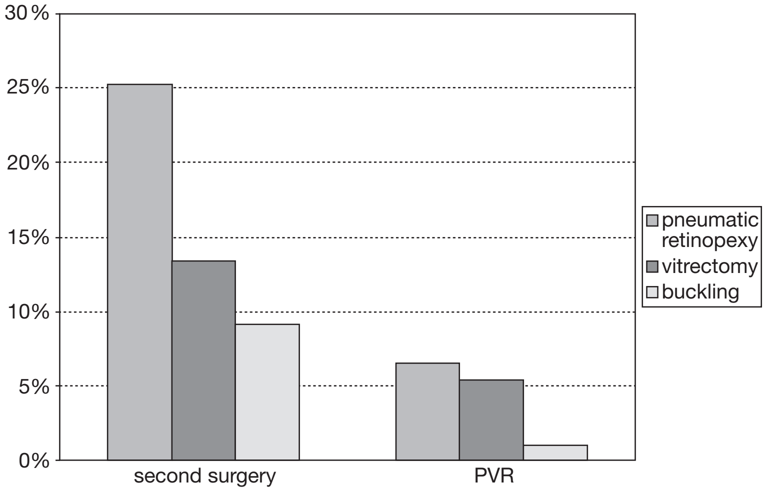

Fig. 8.1. Pool risk of second surgery and proliferative vitreoretinopathy (PVR)

The odds ratio of the pooled procedures, i.e., 3384 intraocular gas operations and vitrectomies versus 1854 extraocular sponge and balloon buckles, for the risk of second surgery, was:

$$\frac{(680/2704)}{(107/1684)} = 2.5 \text{ to } 1$$

and for PVR:

$$\frac{(187/2927)}{(17/1685)} = 6 \text{ to } 1\,.$$

Discussion

In the latter half of the twentieth century, the buckle operations invented by Charles Schepens in 1951 [63] and Ernst Custodis in 1953 [64] were modified and refined. Diathermy was replaced with cryopexy; scleral resections and implants were replaced with explants sutured over full thickness sclera [65, 66]. Extensive circumferential buckles and encircling operations – barrier procedures that were intended to wall away undetected breaks in the periphery – were replaced with segmental buckles confined to the breaks. The undetected break was less frequent because preoperative indirect ophthalmoscopy was augmented by binocular microscopy of the retinal periphery through the mirrors of the Goldmann lens.

Closing the retinal breaks became the sole surgical problem; the extent of the detachment was a lesser factor. If the breaks were effectively buckled, the large detachment would attach without drainage after only a few additional hours (Fig. 8.2). Not draining subretinal fluid was increasingly adopted. At the New York Hospital, the incidence of not draining rose from 50% to 90% in the course of the first 1,000 cases after the senior author (HL) met with Ernst Custodis and adopted his method [67].

Diminished morbidity was the Holy Grail. The external buckle operation with a segmental sponge and without perforation for drainage had no intraocular complications and only infrequent extraocular ones. There was a buckle infection initially of 3% that dropped to 1% with the development of the closed-cell sponge and the use of parabulbar antibiotic [68]. Diplopia might occur if a sponge intruded on a rectus muscle. The substitution of a temporary balloon for breaks beneath a rectus muscle eliminated postoperative diplopia because, within hours after the balloon was withdrawn, the muscle functioned normally again [55]. A second operation after the sponge procedure was required in 11% and after the balloon procedure in 7%. Failure with either the sponge or the balloon was due to an undiscovered break or an inaccurately placed sponge or balloon. Final attachment for the sponge operation after a second buckle was 97% and for the balloon was 99%. Less than 2% developed PVR postoperatively after either procedure. The low incidence of PVR was a positive affect of diminished operative trauma. The greater incidence of PVR as we knew it in prior years was iatrogenic, a product of trauma inflicted by extensive barrier

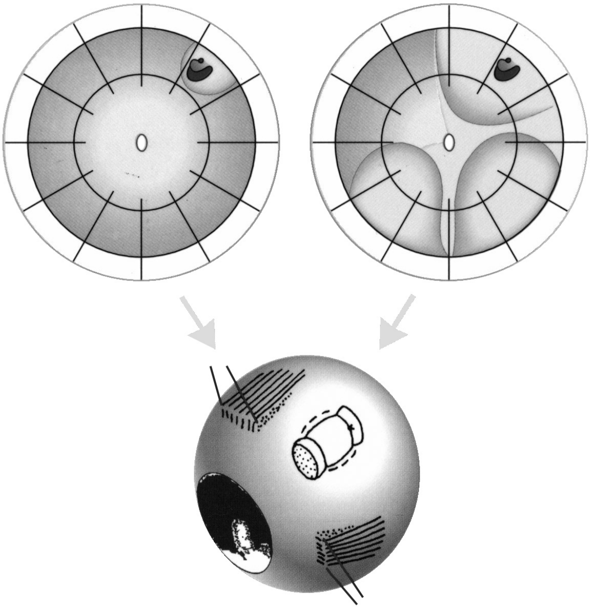

Fig. 8.2. The small detachment (*upper left*) and the more extensive one (*upper right*) both responded to a radial sponge buckle (*lower center*). The larger detachment attached after only a few additional hours

coagulation, constriction by the encircling band, and the draining of subretinal fluid – all of which contribute to a breakdown of the blood–aqueous barrier and the infusion of cells and protein that provoke PVR. Of the 2% that failed to attach because PVR prevented closure of the break with a buckle, vitrectomy could attach half of them. Thus, blindness from a retinal detachment, which was inevitable before 1929, was a rare event at the end of the twentieth century. Why the current swing to an intraocular procedure, which our analysis indicates has a greater morbidity in terms of requiring 2nd surgeries and causing PVR? – We suggest that the reasons are external and not related to results.

Inadequate Training

Vitrectomy is being increasingly employed for primary retinal detachments because the number of doctors trained to do vitrectomy has markedly increased in the past decade, as have the indications for vitrectomy. In addition to the original indications, traction detachment in the diabetic eye and PVR after failed retinal surgery, vitrectomy is done for macular holes, macular puckers, dropped lens and particles, to clear vitreous hemorrhage, and, more recently, to dissect subretinal proliferative lesions in the macula. The indications keep expanding. Retinal detachment can be a relatively infrequent indication for operation on a busy retinal service and of secondary interest. As a result, training for the treatment of retinal detachment may be limited. There are few opportunities outside of the fellowship to learn about buckling. Retinal programs rarely include papers on the subject; it has all been said. Except for William Mieler's short course at the Academy and Ingrid Kreissig's Retinal Detachment Courses at various national and international meetings, there are no workshops on the art of scleral buckling. As a consequence, the coming generation of retinal surgeons may not be very skillful at performing a scleral buckle. In another decade, it is possible that the buckling operation will have become a lost art.

Market Forces

Preparation for a segmental buckle operation can require much study time, frequently hours and sometimes days. A decade ago, if the senior author (HL) could not find a break that promised a 90% prognosis after an hour's study, he would patch both eyes, put the patient at rest, and re-study the eye the next day. Most detachments change with ocular rest, and the change is informative. Today, the insurance companies and Medicare do not allow for an extra day, nor is there payment for study time. It is more expedient to do a vitrectomy and search for the retinal break at the operating table, where the wage rate is 37% higher (Medicare fees from New York, New Jersey, Connecticut). If one does not find the break, a surgeon might be inclined to do a peripheral laser barricade augmented by an encircling band. The barrier operation, which was disappearing near the end of the twentieth century, is returning as a prophylactic supplement to primary vitrectomy and pneumatic retinopexy [54].

Peer Review

A third factor operating against the buckle operation for primary detachment, beyond the lack of training and the limit of reimbursement for the time spent, is the absence of peer review. Preoperative surgical rounds, where the surgical plan for retinal detachment was open for review, suggestion, criticism, and even censure, have disappeared; with 1-day surgery, there is not time for it. The surgeon admits his patient on the day of the operation with as much preparation as his schedule allowed, and, when the patient leaves the hospital later in the day with the eye filled with gas, there is no opportunity to evaluate the effort by his or her peers.

Conclusion

The proponents of primary vitrectomy claim that the final attachment rate after multiple procedures is 99%. In the series that we examined, it was 97%, equal to that of buckling. This is reassuring. They dismiss the morbidity of multiple operations and regard the frequent provocation of cataract as acceptable.

We do not think it is possible to counteract the change in the treatment of retinal detachment. Perhaps market forces will relax, and peer review will return, or maybe new and less morbid methods to attach the retina will be invented. Admittedly, the incidence of second surgery and PVR were beginning to diminish in the most recent of the case series that we examined, and perhaps a way to reduce the incidence of postoperative cataract will develop. If not, maybe in another 50 years, someone will rediscover the scleral buckle.

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Repair of Primary Retinal Detachment: The Present State of the Art and How It Came About

Ingrid Kreissig, Harvey Lincoff

A major advance in the concept of treating a primary rhegmatogenous retinal detachment was the realization that the surgical problem was solely closing the leaking retinal break and that the extent of the detachment or tractional configurations remote from the break are of no consequence. Let us share with you this change in concept over time [1].

Recall, Gonin [2] postulated – for the first time – that a leaking break is the cause of a retinal detachment, and his treatment was limited to the area of this break. With his operation, the attachment rate increased from 0% to 57%. However, this localized procedure was soon modified to coagulations of the entire quadrant of the leaking break. In 1931, Guist and Lindner [3, 4] circumvented further the need for localizing the leaking break by doing multiple cauterizations posterior to the estimated position of the break; Safar [5] applied a semicircle of coagulations posterior to the break. The intent was to create a "barrier" of retinal adhesions posterior to the leaking break. As a result, the treatment was no longer limited to the break, but was expanded over the quadrant in which the break or presumed breaks were located.

In 1938, Rosengren [6] again limited – now for the second time – the coagulations to the leaking break. In addition – and for the first time – he added an intraocular tamponade of air, which was positioned in the area of the break to provide an internal support during the formation of retinal adhesion. Retinal attachment increased to about 77% with Rosengren's procedure.

However, the precise placement of coagulations around the break was difficult, and the Rosengren technique was not widely

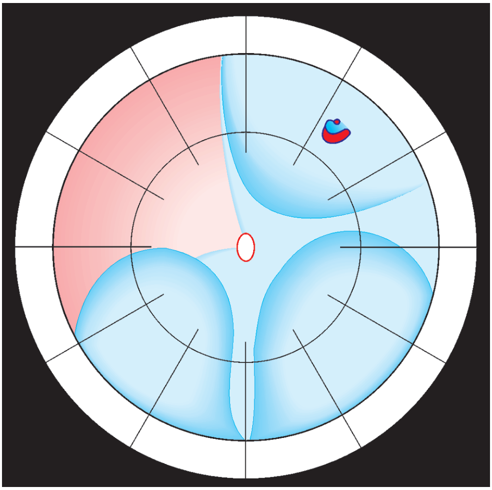
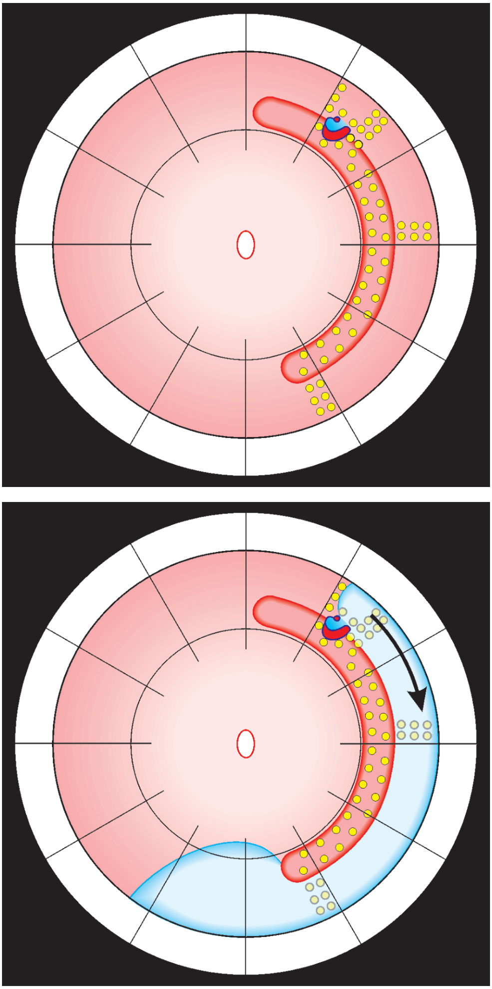


Fig. 9.1. A three-quadrant detachment with a horseshoe tear at 1:15

adopted. Instead, the pendulum swung back to an extensive coagulation. Now, for the second time, the barrier concept was integrated into the treatment. Coagulations were placed posterior to the break, but, in addition, the barrier of coagulations was reinforced with a scleral resection. Subsequently, a polyethylene tube was embedded into the resection to create a higher wall. Thus, for the first time, a buckle was applied in detachment surgery to more effectively barricade the break (Figs. 9.1, 9.2). The break was

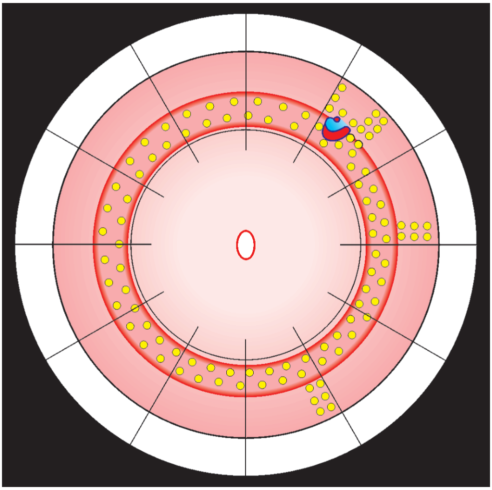
Fig. 9.2. Scleral resection with an embedded polyethylene tube and drainage for repair of the three-quadrant detachment in Fig. 9.1. **a** The horseshoe tear was attached, but positioned on the anterior edge of the buckle and not sufficiently tamponaded. Diathermy coagulations were added around the tear, on the buckle, and additional lines of coagulations extended to the ora serrata. **b** The horseshoe tear leaked anteriorly, broke through the lines of coagulations before the adhesions were secure, and caused an anterior redetachment that progressed inferiorly and redetached the posterior retina



a

b

Fig. 9.2a,b. Legend see page 178



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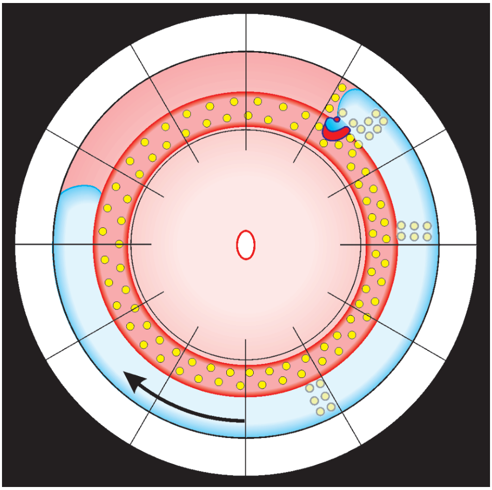


b

Fig. 9.3a,b. Legend see page 181

c

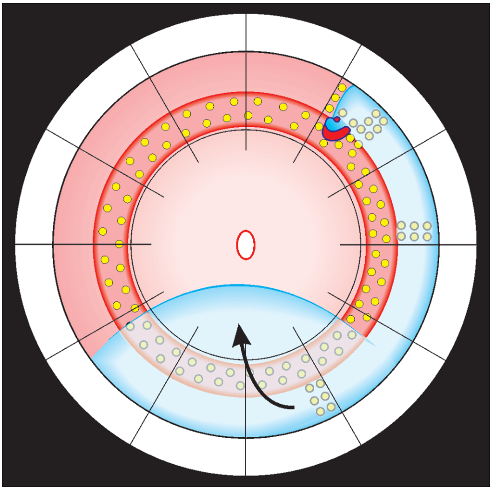


Fig. 9.3. Encircling buckle (cerclage), extensive diathermy coagulations, and drainage for repair of the detachment in Fig. 9.1. **a** The horseshoe tear was attached, but positioned on the anterior edge of the buckle and not sufficiently tamponaded. **b** Anterior redetachment was confined by the encircling buckle. **c** Anterior redetachment eventually broke over the inferior buckle barrier and redetached the posterior retina

positioned at the anterior edge of the buckle and larger breaks were not adequately tamponaded and would leak anteriorly and cause an anterior redetachment, which descended behind the buckle, went around the buckle inferiorly, and redetached the posterior retina.

The consequence could have been a more sufficient tamponade of the leaking break. Instead, a more effective barrier was developed in 1953, the segmental buckle barrier was extended for 360° – for the first time – by Schepens [7] and in 1958 by Arruga [8]. The cerclage operation with drainage of subretinal fluid represented a maximum barrier for the leaking break. But here, as well, redetachments developed (Fig. 9.3). Eventually the cerclage was widened in the area of the tear with a polyethylene sleeve to buckle the anterior edge of the tear. Later, various silicone forms for buckling were designed to fit the tear combined with coagulations limited to the tear or extending over 360° (Fig. 9.4). More retinas were attached – more than 80%.

The modified cerclage with drainage represents one of the four techniques still in use for repair of a primary retinal detachment at the beginning of the twenty-first century (Fig. 9.4). Drainage, however, required by this technique, has complications.

In 1953, Custodis [9] limited the treatment – now for the third time – to the area of the leaking break, but – for the first time – omitted drainage of subretinal fluid. This exceptional technique was nearly abandoned, not because it did not work, but because of unexpected postoperative complications caused by diathermy and the polyviol plombe, which Custodis compressed over full-thickness and diathermized sclera, which sometimes caused scleral necrosis. As a result, the technique was abandoned in the United States and in Europe.

Lincoff in New York, who was convinced of the logic and simplicity of the Custodis procedure, made the operation acceptable by replacing diathermy with cryopexy [10, 11] and the polyviol plombe with the tissue-inert silicone sponge [12]. In the following years, this technique was further refined by smaller segmental buckles that were positioned more precisely [13] and by replacing the sclera-fixated sponge with a temporary balloon buckle [14, 15] that was not sutured onto sclera. The balloon operation was suitable for detachments with a single break. This minimal segmental buckling with sponges or a balloon represents an extraocular approach, limited, again, to the area of the leaking break.

However, the "conditio sine qua non" for a spontaneous attachment without drainage was that all of the leaking breaks had to be found and tamponaded adequately. Otherwise, the disappearance of subretinal fluid would not occur. Finding all the breaks was helped by the development of binocular indirect ophthalmoscopy, biomicroscopy with contact lenses, the 4 Rules to find the break in a primary detachment [16, 17], and the 4 Rules to find the break in an eye up for reoperation [18, 19].

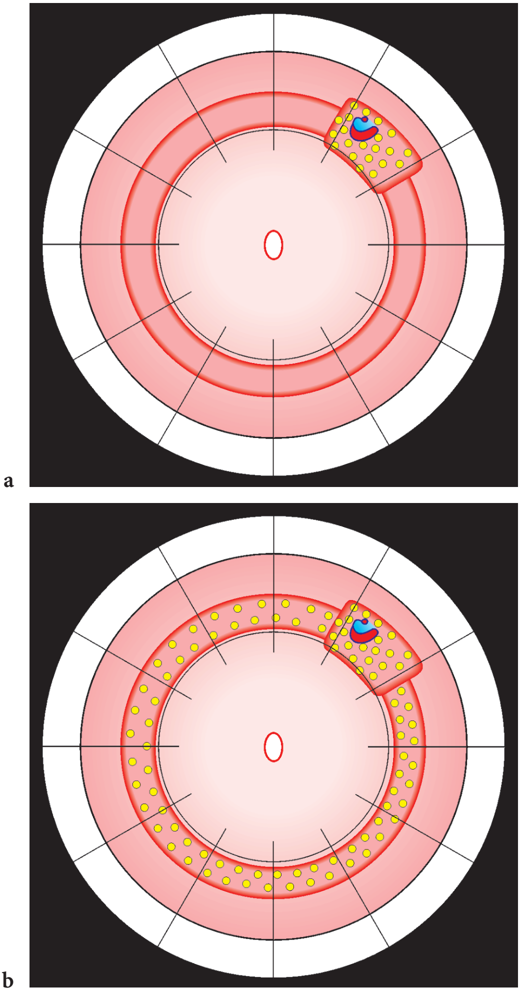


Fig. 9.4. Modified cerclage: Encircling silicone band with a local buckle beneath the tear and drainage for repair of the detachment in Fig. 9.1. With coagulations limited to the area of the tear (**a**) or with coagulations extended for 360° (**b**)

As a result, minimal segmental buckling with sponge(s) or a balloon without drainage represents a second option for repair of a primary retinal detachment in use at the beginning of the twenty-first century (Fig. 9.5).

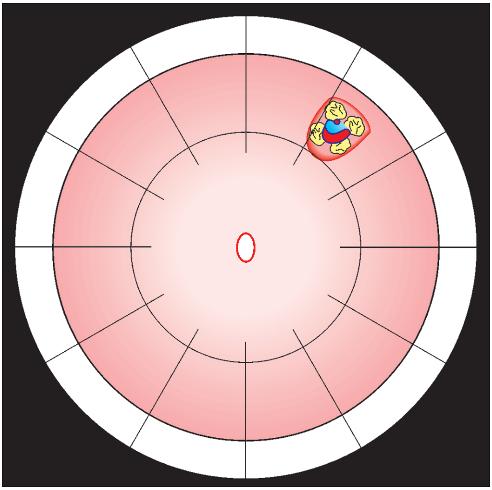
Apart from these two options for closing the leaking break with a circular barrier (cerclage) or a segmental buckle (sponge or balloon) limited to the break, both of which are extraocular, two options for an intraocular approach developed. An intraocular gas bubble to tamponade a leaking break was introduced – now for the second time. Instead of air, SF6 was injected by Norton and Lincoff [20, 21]. This technique required drainage of subretinal fluid with its complications.

In 1979, Kreissig [22] applied – for the first time – intraocular SF6, an expanding gas, without prior drainage in selected detachments. The procedure was named the expanding-gas operation without drainage. However, an increased rate of postoperative proliferative vitreoretinopathy (PVR) caused Kreissig to reserve intraocular gas for problematic breaks not suitable for buckling. Subsequently to reduce the morbidity of intraocular gas, Kreissig developed the balloon-gas procedure which enables to inject primarily a larger bubble of a gas with a shorter intraocular duration [23]. To close a leaking break with a gas bubble and without prior drainage was introduced again – for the second time – by Hilton [24] and simultaneously by Dominguez [25] in 1986.

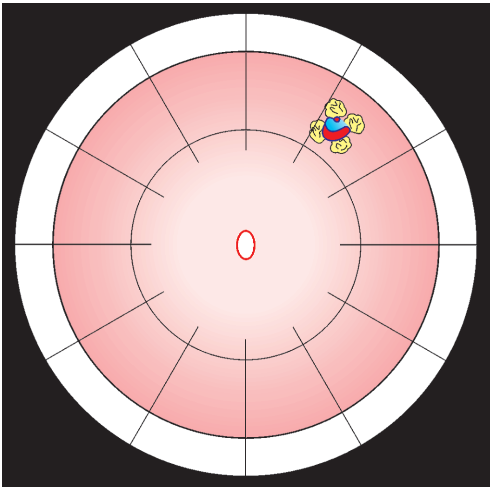
Hilton called the procedure pneumatic retinopexy which represents a third option for repair of a primary retinal detachment in use at the beginning of the twenty-first century (Fig. 9.6a). When supplemented by 360° barrier coagulations, it is no longer a procedure limited to the break (Fig. 9.6b) [26].

Pneumatic retinopexy has become a popular procedure, despite the fact that it has a greater morbidity for closing the leaking break than minimal segmental buckling without drainage. Its popularity is due to its relative simplicity.

To reduce the postoperative complications of intraocular gas, a vitrectomy was added [27]. The rationale was that a vitrectomy



a



b

Fig. 9.5. Minimal segmental buckling without drainage and coagulations limited to the tear for repair of the detachment in Fig. 9.1. The buckle is obtained by a radial sponge (**a**) or by a temporary balloon beneath the tear (**b**). After withdrawal of the unsutured parabulbar balloon (after 1 week), the tear will be only secured by coagulations

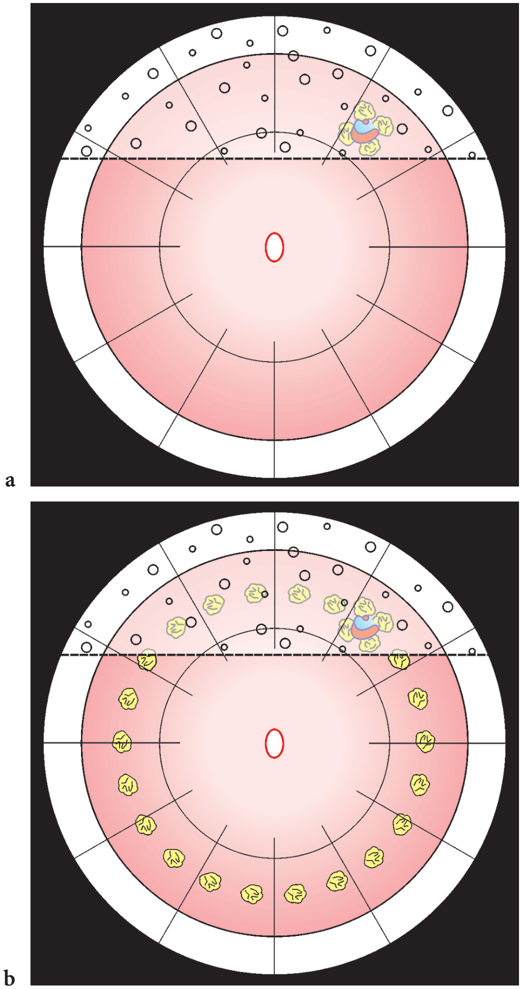
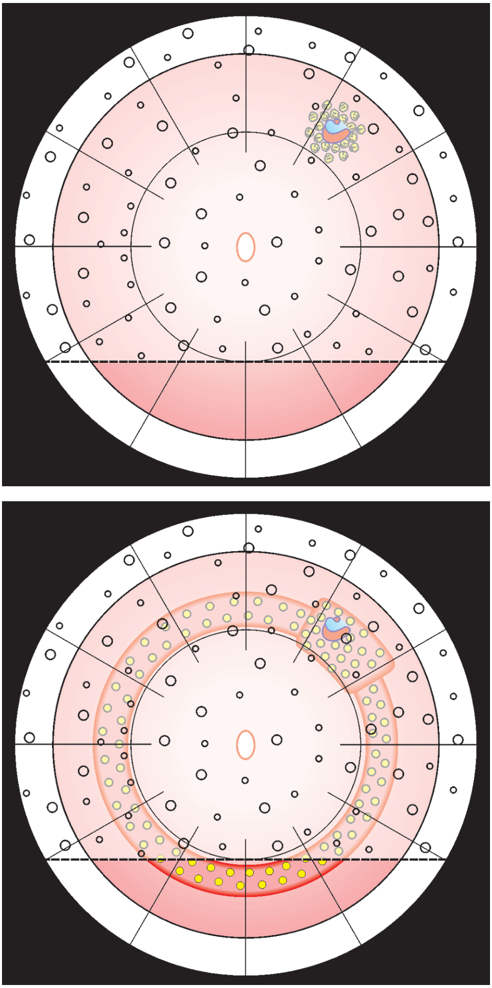


Fig. 9.6. Pneumatic retinopexy without drainage for repair of the detachment in Fig. 9.1. With coagulations limited to the tear (**a**) or with coagulations extended for 360° (**b**) [25]. An expanding gas was injected into the vitreous, and the patient's head was positioned so that the gas bubble tamponaded the tear. Air travel will be restricted until the volume of the gas bubble is less than 10% of the ocular volume



a

b

Fig. 9.7. Primary vitrectomy with resection of the vitreous and internal drainage for repair of the detachment in Fig. 9.1. With coagulations around the tear (**a**) or with coagulations extended for 360°, a local buckle beneath the tear and an encircling band (**b**). Gas was injected to replace the vitreous and the patient asked to avoid face up during sleep. Air travel will be restricted until the volume of the gas bubble is less than 10% of the ocular volume

might eliminate traction on the break and reduce postoperative anterior and posterior vitreous proliferation. The analysis in Chap. 8 indicates that this aim has not been achieved; nevertheless, the procedure is increasingly applied.

Primary vitrectomy has become a fourth option for repair of a primary retinal detachment at the beginning of the twenty-first century (Fig. 9.7). When supplemented by extensive barrier coagulations and a cerclage, it is no longer a procedure limited to the break.

Conclusion

In the beginning of the twenty-first century, the present state-of-the-art for repair of a primary retinal detachment has reverted from a local to a barrier concept of treatment – as has happened several times during the past 75 years.

External buckling: local buckles with coagulations limited to the break (Fig. 9.5a, b) are becoming replaced by local buckles supplemented by an encircling band with extended coagulations (Fig. 9.4a, b), applied as a barrier against redetachments.

The same applies to pneumatic retinopexy: the primary intent to limit treatment to the area of the tear (Fig. 9.6a) is given up – again – in favour of a barrier concept by applying 360° of coagulations (Fig. 9.6b).

A similar trend is becoming apparent with primary vitrectomy: initially aimed at removing traction on the tear and limiting the coagulations to the area of the tear (Fig. 9.7a), the procedure has been extended by a circular barrier of coagulations with an encircling band supplemented by a local buckle beneath the tear to prevent redetachments (Fig. 9.7b).

Of the four surgical techniques in use at present for repair of a primary rhegmatogenous retinal detachment, two are extraocular operations (minimal segmental buckling with sponges or a balloon without drainage and cerclage with drainage) and two are intraocular (pneumatic retinopexy and primary vitrectomy). To succeed with any of these methods, the leaking break still has to be found and sealed. Therefore, finding and closing the retinal break in a rhegmatogenous retinal detachment will continue to be the primary purpose of any surgical effort.

With any of the four presently applied surgical techniques, retinal attachment can result in 94–99% of primary rhegmatogenous retinal detachments, but with different degrees of morbidity. At this point in time, we must wait to see which of these four procedures or their extended modifications will prevail or whether a better and less morbid method for repair of retinal detachment will evolve.

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Retinal Detachment Repair: Outlook for the Future

William R. Freeman

Due to the pioneering work of many ophthalmologists, including Gonin, Lincoff, and others, the basic pathophysiology of rhegmatogenous retinal detachment has been established. A retinal tear is caused by a vitreous detachment and traction on the retinal tear, and peripheral retina is responsible for fluid currents, which go through the break and detach the retina. More fundamental questions remain to be answered and will have important implications for our ability to detect, prevent, and treat rhegmatogenous retinal detachment and its complications.

Many controversies remain regarding surgical repair of this disease. This controversy is complicated due to a lack of prospective randomized clinical trials comparing different methods of

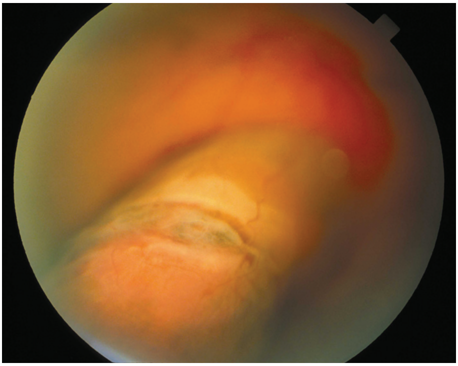

Fig. 10.1. Radial sponge has cured a retinal detachment without the need for drainage

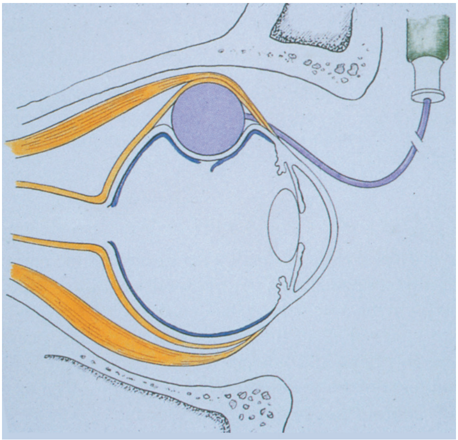

Fig. 10.2. Balloon buckle in place closing retinal break

treatment. For this reason, much of the debate revolves around theory and philosophy, not hard clinical data. There is little doubt that the most minimal operation that would be highly effective would be the procedure of choice. Highly effective should include minimal complications and inconveniences, such as the induction of refractive error (Lincoff, Kreissig) [1]. In this regard, the classical radial sponge (Fig. 10.1) or the balloon buckle (Fig. 10.2) remains the gold standard for many, due to the extraocular nature of the surgery and low complication rate. These procedures shared in common extraocular placement of a bulky device, which reapposes or nearly apposes the neurosensory retina and retinal pigment epithelium/choroicapillaris. By bringing these two layers in close proximity, the rate of fluid flow under the retina is limited and the pumping action of the pigmented epithelium overcomes the leakage of fluid through the retinal tear; thus the retina reattaches. The use of retinopexy is a backup procedure to further prevent fluid leakage, causing a permanent scar or adhesion of the two layers (Figs. 10.3 and 10.4). Unfortunately, segmental buckling is not

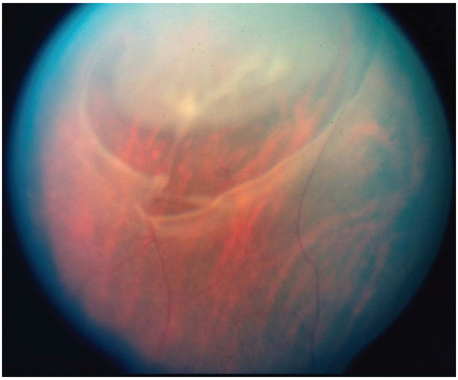

Fig. 10.3. Horseshoe retinal tear with vitreous traction

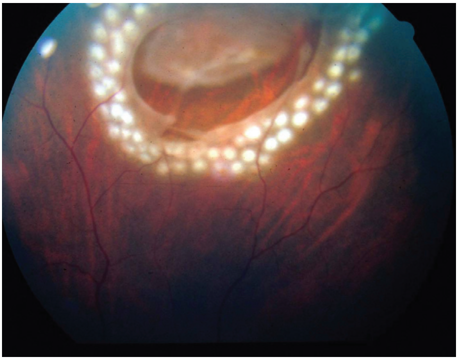

Fig. 10.4. Laser retinopexy surrounding horsehoe retinal tear

applicable to all cases. For example, very large posterior tears are difficult to externally tamponade. Giant retinal tears do not respond to external buckle procedures because one cannot reappose the layers; the retina is merely pushed inward. In addition, the procedure can only work when all retinal breaks can be well visualized (Fig. 10.5). This may be difficult in eyes with media problems or

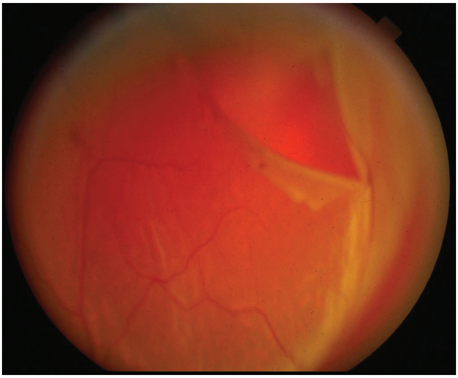

Fig. 10.5. A well-visualized peripheral retinal tear

when intraocular lenses, retained lens material, and other difficulties preclude identification of all retinal breaks [2].

Let us now consider the evolution of surgical techniques in the future. One of the many obstacles to performing minimal buckling techniques, as well as pneumatic retinopexy and the balloon buckle, is the difficulty in finding all retinal breaks in certain eyes as outlined above. New techniques will evolve to allow visualization of the peripheral retina, which will make break identification more universally possible.

New imaging techniques, such as ballistic light imaging (Fig. 10.6), hold the promise of high-resolution trans-scleral optical images [3]. Ordinarily, it is not possible to view clearly through a semi-transparent tissue, such as the thin sclera. A degraded image results due to scattered light. Light passes through the tissue, but scatter presents the ability to obtain a clear image. Scattered light is delayed compared with non-scattered light; however, the amount of delay is extremely small. The ability to fabricate femtosecond optical filters can theoretically gate out this scattered light based on time differences. In the future, such ballistic light imaging promises to be a non-invasive way of examining the vitre-

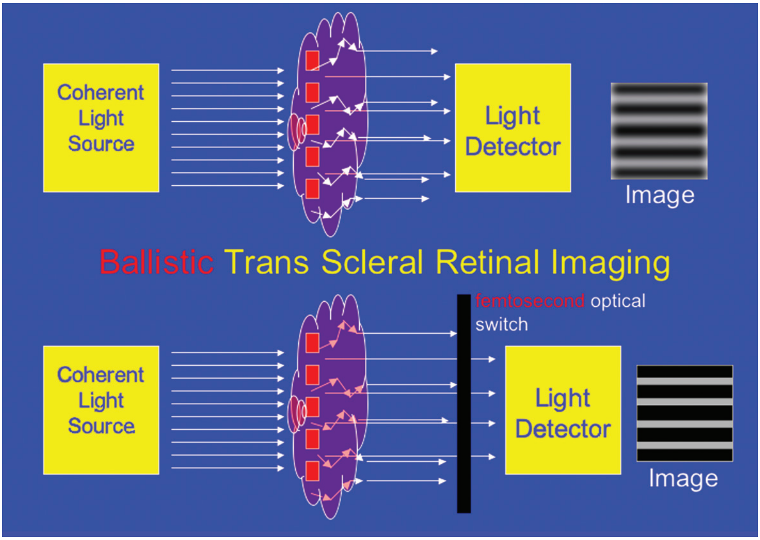

Fig. 10.6. Trans-scleral retinal imaging (scattering media)

ous base area at high resolutions and will be particularly helpful in cases of small pupils, intraocular lenses with anterior capsular phimosis, and other conditions. A trans-scleral imaging probe could be used with topical anesthesia and would allow thorough examination of the peripheral retina at high magnification, similar to how ultrasound is currently used. Additional imaging techniques, which may be applicable to detect retinal breaks, include higher resolution and intraoperative ultrasound biomicroscopy that is easier to use (Fig. 10.7). Current techniques are limited by awkwardness of probe placement and large instrumentation; but, this should change in the future. The use of ultrasound will not actually visualize retinal breaks optically; however, clearly, breaks can be identified by ultrasound, particularly using high-resolution techniques. Ophthalmoscopic techniques that involve visualization of the retina through the optical media of the eye are also evolving;

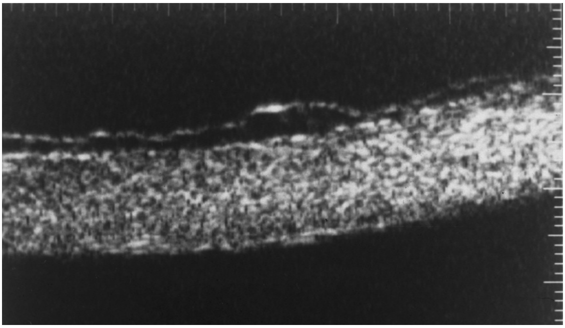

Fig. 10.7. Ultrasound biomicroscopy images peripheral retinoschisis

Fig. 10.8. Pseudo-color wide-angle scanning laser may allow screening for retinal detachment

the wide-angle pseudo-color SLO and related techniques (Fig. 10.8) may allow noninvasive screening for retinal detachment by primary care health care providers, which will allow us to treat detachments prior to macular involvement [4]. Such wide-angle SLO devices currently do not allow reliable imaging of structures anterior to the equator of the globe; however, they can detect retinal detachment early and, if set up as easy to use screening devices, will allow

Fig. 10.9. Vitreous endoscopy allows visualization of far anterior structures such as the ciliary body and pars plana

patients to be treated at earlier stages of the detachment, when the macula has not been affected, and the rate of success is higher. High-resolution scans, such as those used now for magnetic resonance imaging (MRI) scanning of the head and neck vessels, may become applicable to the retinal periphery and help with break localization and prophylaxis issues. Functional MRI may increase our understanding of peripheral retinal tissues as well. This technique may allow insights into vitreous and peripheral retina metabolism and degeneration and may help allow us to predict those at risk for early vitreous detachment and retinal detachment [5]. Intraoperative techniques will evolve, and these will include even better wide-angle viewing systems and the future use of stereoscopic endoscopy, which will allow the advantages of stereoscopic viewing and tissue manipulation currently not possible with grin and other forms of endoscopy [6] (Fig. 10.9). New lasers may allow us to transect the flaps of flap tears, thereby relieving traction; if this is possible, retinopexy may not even be required, and minimal manipulations to close the break may be possible. Electron knives and other devices will be able to be used intraoperatively to allow tissue to be cut in a non-traumatic and, therefore, non-pro-inflammatory manner.

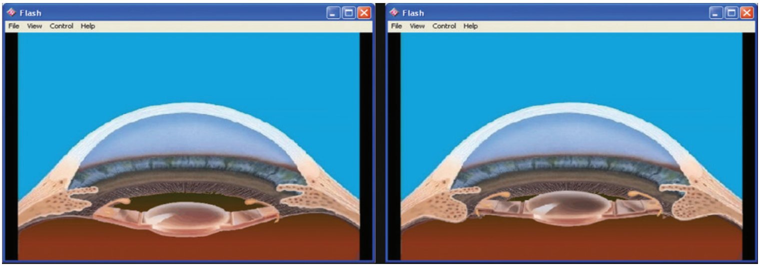

Fig. 10.10. Accommodating intraocular lens (IOL): two positions. IOL moves with ciliary body contraction

In the future, the incidence of pseudophakia will be much higher. Anterior segment surgeons will be implanting accommodating intraocular lenses (IOLs) to treat presbyopia (Fig. 10.10). The development of this and other lens replacement devices to treat presbyopia and, potentially, low vision will increase the number of eyes that have had cataract surgery, and this will likely increase the prevalence of retinal detachment [7]. The technologies of accommodating IOLs being currently developed do entail an intact posterior capsule and the use of capsulorhexis, so the difficulties of viewing the peripheral retina using our current technologies will need to be addressed (Fig. 10.11). Multizone phakic

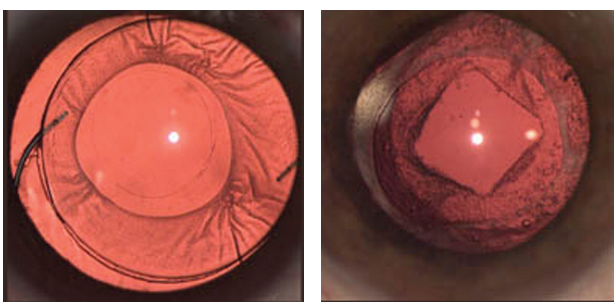

Fig. 10.11. Phimosis of anterior capsule limits peripheral retina visualization

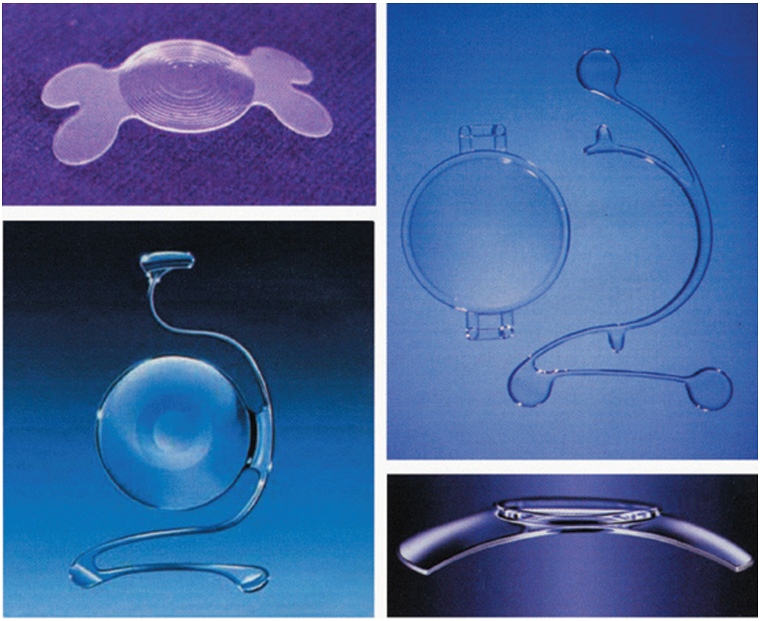

Fig. 10.12. Several types of multifocal intraocular lenses

IOLs for presbyopia will also complicate our view in the future as their use becomes widespread (Fig. 10.12).

Let us also consider clinical trials of the future. Clearly, the current clinical trials methodologies in use are awkward, expensive, and extremely personnel intense. Anybody who has participated in a definitive National Institutes of Health or drug company trial knows this. These trials take years to plan and, by definition, cannot test cutting edge techniques and are not applicable to techniques in evolution. The paperwork and infrastructure currently required to perform high-quality clinical trials is extremely cumbersome and inefficient. Let us consider the concept of the Secure VPN or Virtual Private Network (Fig. 10.13). Consider that groups of surgeons will be securely networked and will have the power to

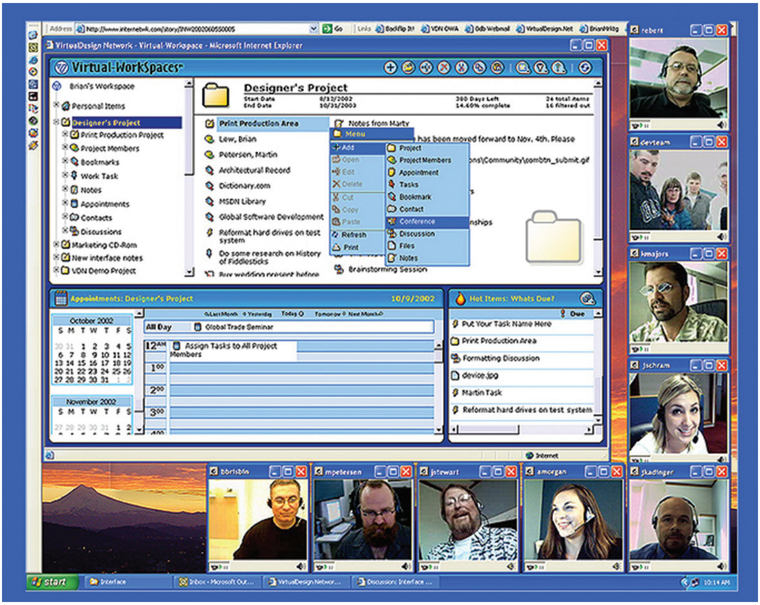

Fig. 10.13. Virtual personal collaborative networks

query the sum experience of the group. Imagine that data will be ferreted out because all data will be computerized and that sophisticated programs, worms, and internet cookies will allow compilation of preoperative data, procedure data, and outcomes, including standardized visual acuity. In addition, patients will be able to be contacted to determine quality of life outcomes. Although all procedures may not be standardized, standardization can evolve and may allow us to collect real time data and outcomes as they occur in patients throughout the United States or the world. One can only imagine what the ability to determine success and outcomes nationally and internationally will do to our ability to advance and understand surgical techniques when such information will be available with minimal effort in comparison with today's clinical

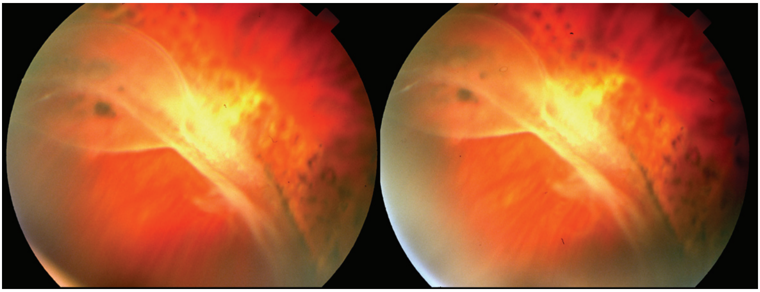

Fig. 10.14. Stereo photograph of old giant retinal tear with cyst. Fellow eyes are at high risk

trial techniques. The network of academic collaborations will be able to be formalized, and individual physicians will be able to collaborate seamlessly. Clinical science will also advance as we learn more about genetics and other cofactors that predispose to retinal detachment. Our knowledge of who is at high risk for retinal detachment remains rudimentary. We know that fellow eyes are at risk, particularly in certain conditions (Fig. 10.14); but there remains great controversy as to the role of prophylaxis of peripheral retinal lesions that may be related to retinal detachment. Clearly, as we learn more about risk factors, the role of different types of prophylaxis will become better understood. This, in conjunction with more facile ways to perform clinical trials and surveys, will allow preventive treatment algorithms to evolve.

The pioneering work of Sawa and Tano in Osaka has shown us that it is not instrumentation of the vitreous itself, but infusing of fluids that is likely the cause of nuclear sclerosis and cataract induction after vitrectomy [8]. As vitreous surgery is applied to eyes with relatively good visual potential, the side effect of cataract is more clinically important. Our indications for vitrectomy in the repair of retinal detachment and for other diseases may expand considerably if we can avoid cataract formation in these eyes.

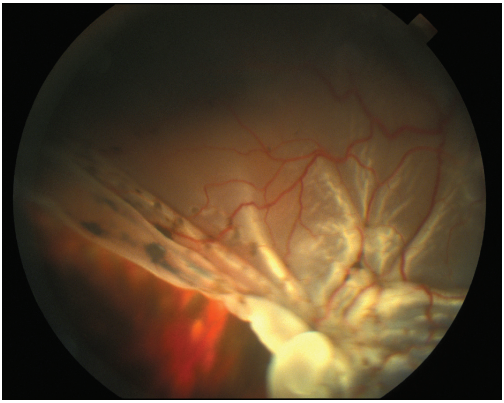

Fig. 10.15. Proliferative vitreoretinopathy

Finally, let us not forget drug treatment and pharmacotherapy in the area of retinal detachment. One of the main nemeses of retinal detachment surgeons is proliferative vitreoretinopathy (PVR) (Fig. 10.15). This is the result of a biological process gone awry. Cellular elements already in the eye and, in some cases in the blood, proliferate, lay down collagen, and cause collagen contraction. This biological process results in membrane formation, recurrent retinal detachment, and macular pucker. There has been widespread study of the classical antiproliferatives to reduce the risk of PVR or to limit it. These drugs, such as 5FU and Daunomycin, are intrinsically toxic. We will soon be using the techniques of molecular biology and intelligent drug design to create more sophisticated anti-proliferative drugs. Such drugs may take the shape of the hammerhead ribozyme, which cleaves mRNA involved in proliferation and other processes (Fig. 10.16). These types of drugs are similar to antisense, but unlike antisense are recycled intracellularly [9]. Thus, they may be able to be applied into the eye and remain active in cells for months or longer. There will be other ways to block this biological process, including acting on inflammation, proliferative pathways, and cytokine pathways. The

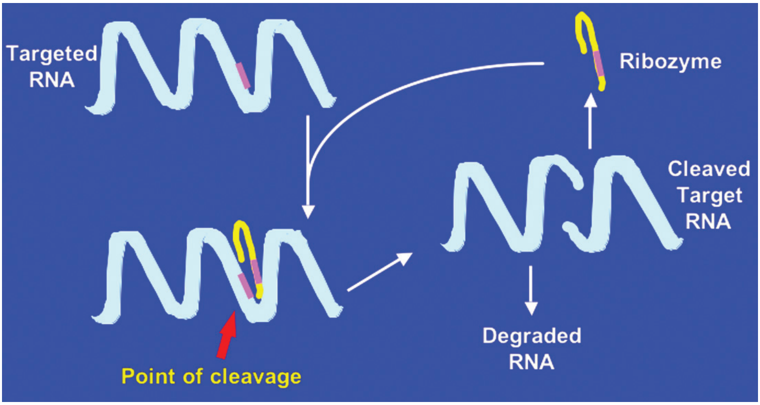

Fig. 10.16. Ribozyme cleavage of RNA associated with cell proliferation

role of other cellular pathways in proliferation and cellular damage is being explored by many basic scientists. We have yet to take full advantage of molecular drug design to inhibit the pathways involved in PVR. Similarly, as we elucidate the roles of cytokines and develop non-toxic inhibitors of these molecules, we can use this knowledge to inhibit (Fig. 10.17).

Similarly, our understanding of what damages the retina after retinal detachment and new drugs to stabilize this delicate neural tissue will be developed, which will also result in better visual outcomes, even in more long-standing macula off retinal detachment. We can now design functional peptide-based drugs and will be able to incorporate signaling peptides into nanofibers (Fig. 10.18) and engineer an instructional matrix for stem cells to replace and repopulate maculae with damaged photoreceptor elements [10]. In vivo fluorescence staining and other cell and molecular techniques are allowing us to visualize pathology in living cells as we see here, using fluorescence microscopy in vivo to follow cell motion with cytoskeletal marker staining. Understanding these fundamental processes will help prevent and treat intraocular proliferative diseases, such as PVR.

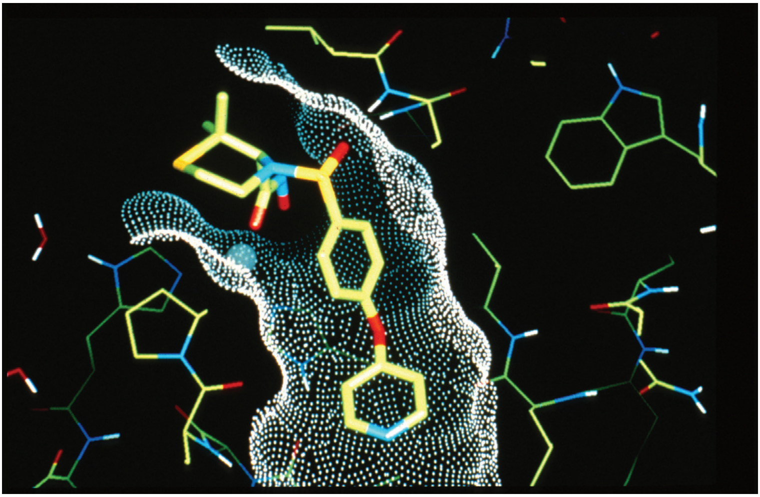

Fig. 10.17. Small molecule inhibits matrix metalloproteinase enzyme involved in angiogenesis

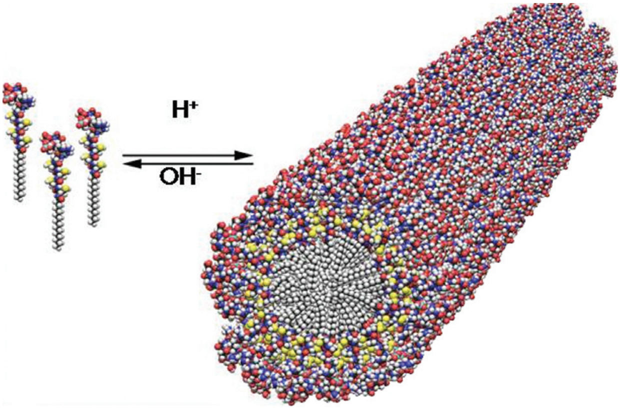

Fig. 10.18. Cross-linked self-assembling peptide nanofibers

It is impossible to know what the future holds. The ever-accelerating progress of scientific discovery and the desire of vision scientists and ophthalmologists to help patients will assure us that new and exciting tools and techniques will evolve to take us to where we have not been or even dreamt before.

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