The History of Retinal Detachment Surgery

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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

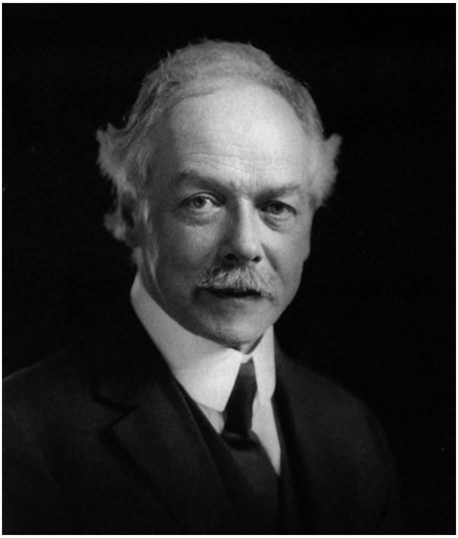

Fig. 1.1. Jules Gonin. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

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 thermocautery (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].

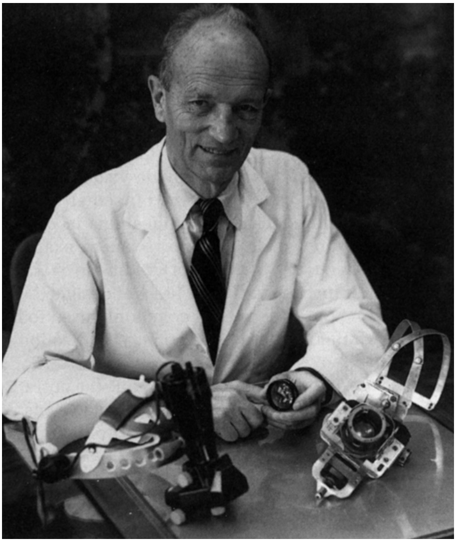

Fig. 1.3. Charles L. Schepens. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

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

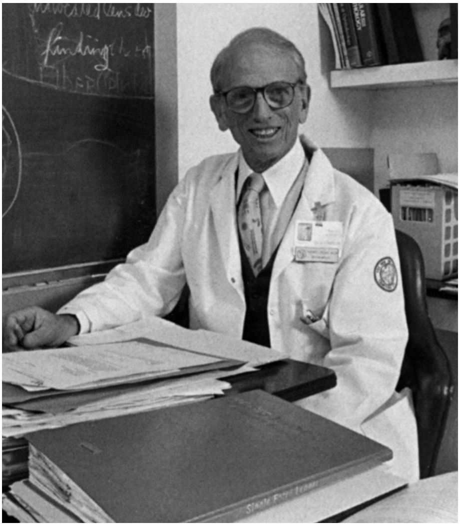

Fig. 1.4. Harvey Lincoff. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

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.

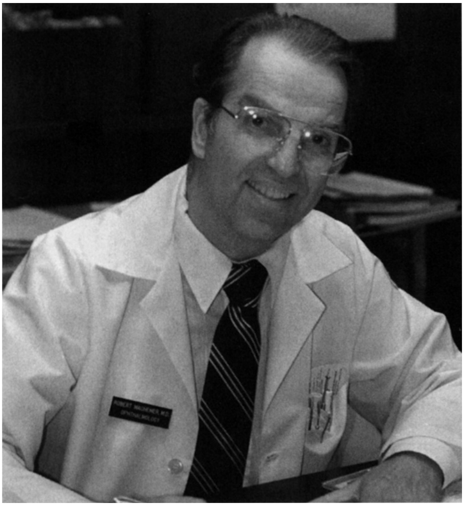

Fig. 1.5. Robert Machemer. (Reproduced with permission; Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby St. Louis MO. pp 241–333 [10])

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.

References

1. Ware J (1805) Surgical observations relative to the eye, 2nd edn. London, pp 1–510
2. Wardrop J (1818) Essays on the morbid anatomy of the human eye. Edinburgh, pp 2–64
3. Panizza B (1826) Sul fungo midollare dell'occhio. Pavia
4. Rucker CW (1971) A history of the ophthalmoscope. Whiting Printers, Rochester, MN, p 23
5. Coccius A (1853) Ueber die Anwendung des Augenspiegels nebst Angabe eines neuen Instruments. Immanuel Mueller, Leipzig, p 131
6. von Graefe A (1854) Notiz ueber die im Glaskoerper vorkommenden Opacitaeten. Arch f Ophthalmol 1:351
7. Gonin J (1919) Ann Oculist Paris 156:281
8. Gonin (1920) Bull Soc Franc Ophthal 33:1
9. Duke-Elder S, Dobree JH (1967) Detachment and folding of the retina. In: Duke-Elder S (ed) System of ophthalmology, vol 10: diseases of the retina, Mosby-Year Book, St. Louis, pp 816–822
10. Wilkinson CP, Rice TA (1997) Michels retinal detachment, 2nd edn. Mosby, St. Louis, MO, pp 241–333
11. Stellwag C (1861) Lehrbuch der praktischen Augenheilkunde. Wilhelm Braumueller, Vienna
12. Donders (1866) Die Anomalien der Refraction und Accomodation des Auges. Wien

13. Samelsohn J (1875) Ueber mechanische Behandlung der Netzhautabloesung. Zentrablatt fuer die Medizinischen Wissenschaften 49:833
14. Mendoza R (1920) Rev Cubana Oftal 2:143
15. Marx V (1922) von Graefe's Arch Ophthalmol 108:237
16. Ware J (1805) Chirurgical observations relative to the eye, vol 2, 2nd edn. J Mawman, London, p 238
17. von Graefe A (1863) Perforation von abgeloesten Netzhaeuten and Glaskoerpermembranen. Arch f Ophthalmol 9:85
18. Martin G (1881) VII Int Cong Med 3:110
19. de Wecker, M (1882) Ann Oculist Paris 87:39
20. Dor H (1907) Meine frueheren Erfolge in der Behandlung der Netzhautabloesung. Ophthalmol Klin 11:618
21. de Wecker (1872) Ann Oculist Paris 68:137
22. Robertson A (1876) Roy Lond Ophthal Hosp Rep 8:104
23. Groenholm (1921) Von Graefes Arch Ophthalmol 105:899
24. Wiener (1924) Arch Ophthalmol 53:368
25. Grossman K (1883) On the mechanical treatment of detached retina. Ophthalmic Rev 2:289
26. Mellinger JB (1896) Augenheilanstalt in Basel. 32:79
27. Deutschmann (1895) Beitr Augenheilk 2:850
28. Mueller L (1903) Eine neue operative Behandlung der Netzhautabhebung, Klin Monatsbl Augenheilkd 41:459
29. Torok E (1920) Results obtained with Mueller's resection of the sclera in detachment of the retina due to high myopia. Arch Ophthalmol 49:506
30. Lagrange JL (1912) Moyens chirurgicaux pour combattre l'hypotonie oculaire. Rev Gen d'Ophtalmol 32:379
31. Carbone (1925) Atti Cong Soc Oftal Ital, p 301
32. Ohm J (1911) Ueber die Behandlung der Netzhautabloesung durch operative Entleerung der subretinalen Fluessigkeit und Einspritzung von Luft in der Glaskoerper. Arch f Ophthalmol 79:442
33. Nakashima (1926) Von Graefes Arch Ophthalmol 116:403
34. Rohmer L (1912) Effets des injections d'air sterilize dans le vitré contre le décollement de la rétine. Arch d'Ophthalmol (Paris) 32:257
35. Jeandelize B (1926) Arch Ophthalmol 43:413
36. Szymanski (1933) XIV Int Cong Ophthal Madrid 2:51
37. Meyer E (1871) Traite des operations que se pratiquent sur l'oeil. Paris
38. Galezowski X (1890) Du traitement du décollement de la rétine. Arch f Augenheilkd 21:146

39. Vail DT (1912) An inquiry into results of the established treatment of detachment of the retina and a new theory. Trans Am Acad Ophthalmol Otolaryngol 17:29
40. Colyear BH, Pischel DK (1956) Clinical tears in the retina without detachment. Am J Ophthalmol 41:773–792
41. Gonin J (1930) The treatment of detached retina by sealing the retinal tears. Arch Ophthalmol 4:621
42. Duke-Elder S, Dobree JH (1967) Detachment and folding of the retina. In: Duke-Elder S (ed) System of ophthalmology, vol 10: diseases of the retina. Mosby-Year Book, St. Louis, p 772
43. Rumpf J (1976) Jules Gonin. Inventor of the surgical treatment for retinal detachment. Surv Ophthalmol 21:276
44. Brown AL (1930) Gonin's cautery puncture for detached retina. Report of three cases. Trans AMA Sect Ophthalmol 81:236
45. Rosengren B (1952) 300 cases operated upon for retinal detachment; method and results. Acta Ophthalmol 30:117–122
46. Lindner K (1933) Heilungsversuche bei prognostisch unguenstigen Faellen von Netzhautabhebung. Z Augenheilkd 81:227
47. Bordley W (1949) The scleral resection (eyeball-shortening) operation. Trans Am Ophthalmol Soc 47:462
48. Paufique L, Huggonnier R (1951) Traitement du decollement de retina par la resection sclerale: technique personelle, indications, et resultats. Bull Mem Soc Fr Ophthalmol 64:435
49. Dellaporta AN (1951) Die Verkuerzung des Bulbus mittels Sklerafaltung. Klin Monatsbl Augenheilkd 119:135
50. Berliner ML (1952) Lamellar resection of sclera in treatment of retinal detachment. Preliminary report. Arch Ophthalmol 48:596
51. Guist G (1931) Eine neue Ablatiooperation. Z f Augenheilkd 74: 232
52. Lindner K (1931) Ein Beitrag zur Entstehung und Behandlung der idiopathischen und der traumatischen Netzhautabhebung. Arch f Ophthalmol 127:177
53. Imre J (1930) Ber. Deutsch Ophthalmol Ges 48:321
54. Imre J (1932) Surgical therapy of detachment of retina: Die operative Therapie der Ablatio retinae. Orv Hetil 76:245
55. von Szily A, Machemer H (1934) Vergleichende Untersuchungen ueber die Wirkung der verchiedenen operativen Behandlungsmethoden der Netzhautabloesung im Tierexperiment. Klin Monatsbl Augenheilkd 92:44

56. Larsson S (1932) Electro-diathermy in detachment of the retina. Arch Ophthalmol 7:661
57. Weve HJ (1932) Zur Behandlung der Netzhautabloesung mittels Diathermie. Abhandlungen aus der Augenheilkunde no 14
58. Safar K (1932) Behandlung der Netzhautabhebung mit Elektroden fuer multiple diathermische Stichelung. Ber Dtsch Ophthalmol Ges 49:119
59. Walker CB (1934) Retinal detachment. Technical observations and new devices for treatment with a specially arranged diathermy unit for general ophthalmic service. Am J Ophthalmol 17:1
60. Dellaporta A (1954) Endodiathermy. A method of sealing macular holes by transbulbar coagulation. Am J Ophthalmol 37:649
61. Shapland CD (1961) Developments in detachment surgery during the past thirty years. Trans Ophthalmol Soc Aust 21:19
62. Czerny V (1867) Ueber Blendung der Netzhaut durch Sonnenlicht. Ber Wien Acad Wiss 56:2
63. Maggiore L (1927) Contributo sperimentale alle alterazioni retiniche negli occhicemani esposti a luce intense. Atti Congr Soc Ital Oftal, Rome, p 42
64. Meyer-Schwickerath G (1949) Koagulation der Netzhaut mit Sonnenlicht. Ber Dtsch Ophthalmol Ges 55:256
65. Moran-Sales J (1950) Obliteracion de los desgarvos retinianos por quemadura con luz. Arch Soc Oftal Hispano-am 10:566
66. Meyer-Schwickerath G (1960) Light coagulation. Mosby-Year Book, St. Louis, p 18
67. Maiman TH (1960) Stimulated optical radiation in ruby. Nature 493: 493–494
68. Zaret MM, Breinin GM, Schmidt H, et al (1961) Ocular lesions produced by an ocular maser (laser). Science 134:1525
69. Campbell CJ, Rittler CM, Koester CJ (1963) The optical laser as a retinal coagulator. Trans Amer Acad Ophthal Otolaryng 67:58–67
70. L'Esperance FA Jr (1969) Clinical applications of argon laser photocoagulation. Trans Ophthal Soc U K 89:557–573
71. Little HL, Zweng HC, Peabody RR (1970) Argon laser slitlamp retinal photocoagulation. Trans Amer Acad Ophthal Otolaryng 74:85–97
72. Deutschmann R (1933) Ueber zwei Verfahren bei Behandlung der Netzhautabloesung (eines davon der Diathermie scheinbar entgegengesetzt) nebst Bemerkungen zur Genese des Netzhautrisses und seines Verhaeltnisses zur Entstehung der Abloesung. Klin Monatsbl Augenheilkd 91:450

73. Bietti GB (1933) Corioretiniti adhesive da crioapplicazioni episleral. Acta XIV Conc Ophthalmol, (Madrid) 2:12
74. Bietti GB (1934) Criocausticazioni episcleral: con mezzo di terapia nel distacco retinico. Boll Oculist 13:576
75. Krwawicz T (1961) Intracapsular extraction of intumescent cataract by application of low temperature. Br J Ophthalmol 45:279
76. Kelman CD, Cooper TS (1963) Cryogenic ophthalmic surgery. Am J Ophthalmol 56:731
77. Lincoff HA, McLean JM, Nano H (1964) Cryosurgical treatment of retinal detachment. Trans Am Acad Ophthalmol Otolaryngol 68:412
78. Amoils SP (1965) Technique for round pupil cryogenic cataract extraction. Am J Ophthalmol 60:846
79. Mueller L (1903) Eine neue operative Behandlung der Netzhautabhebung. Klin Monatsbl Augenheilkd 41:459
80. von Blaskovic L (1912) Erfahrungen ueber die Muellersche Lederhautresektion gegen Netzhautabloesung. Z Augenheilkd 27:88
81. Paufique, Hugonnier, Moreau (1952) Ann Oculist Paris 185:113
82. Jess (1937) Klin Mbl Augenheilk 99:318
83. Lindner (1949) Wien Klin Wschr 61:206
84. Weve H (1949) Bulbusverkuerzung durch Raffung der Sklera. Ophthalmologica 118:660
85. Custodis E (1956) Die Behandlung der Netzhautabloesung durch umschriebene Diathermiekoagulation und einer mittels Plombenaufnaehung erzeugten Eindellung der Sklera im Bereich des Risses. Klin Monatsbl Augenheilkd 129:476
86. Schepens CL (1953) Prognosis and treatment of retinal detachment. The Mark J. Schoenberg Memorial Lecture. A review by Kronenberg B, New York Society for Clinical Ophthalmology. Am J Ophthalmol 36:1739
87. Schepens CL (1954) New England Ophthalmological Society, 409th Meeting, Dec 17, 1952. Am J Ophthalmol 38:410
88. Schepens CL (1956) Symposium: retinal detachment. In: Lyle D (ed) Society proceedings. Am J Ophthalmol 41:698
89. Schepens CL, Okamura ID, Brockhurst RJ (1957) The scleral buckling procedures. I. Surgical techniques and management. Arch Ophthalmol 58:797
90. Schepens CL, Okamura ID, Brockhurst RJ (1958) The scleral buckling procedures. II. Technical difficulties of primary operations. Arch Ophthalmol 60:84

91. Brockhurst RJ, Schepens CL, Okamura ID (1958) The scleral buckling procedures. III. Technical difficulties of reoperations. Arch Ophthalmol 60:1003
92. Okamura ID, Schepens CL, Brockhurst RJ (1959) The scleral bucking procedures. IV. Reoperations following scleral buckling. Arch Ophthalmol 62:445
93. Schepens CL, Okamura ID, Brockhurst RJ (1958) The scleral buckling procedures. V. Synthetic sutures and silicone implants. Arch Ophthalmol 60:1003
94. Schepens CL (1947) A new ophthalmoscope demonstration. Trans Am Acad Ophthalmol Otolaryngol 51:298–301
95. Brockhurst RJ (1965) Scleral buckling techniques. In: Schepens CL, Regan CDJ (eds) Controversial aspects of the management of retinal detachment. Little, Brown, Boston, p 111
96. Lincoff HA, Baras I, McLean J (1965) Modifications to the Custodis procedure for retinal detachment. Arch Ophthalmol 73:160
97. Kreissig I, Rose, D, Jost B (1992) Minimized surgery for retinal detachments with segmental buckling and nondrainage: an 11-year follow-up. Retina 12: 224–233
98. Strampelli B (1954) Introduzione di spugna de gelatina nello spazio sopracoroideale nella operazions del distacco di retina non riducible con il riposo. Ann Ottalmol Clin Oculist 80:275
99. Borrás A (1961) Inclusion of absorbable gelatin film between the scleral lamellae in the treatment of retinal detachment. Am J Ophthalmol 52:561
100. Jacklin HN, Freeman HM, Schepens CL, Tablante RT (1968) Gelatin as an absorbable implant in scleral buckling procedures. Arch Ophthalmol 79:286
101. Wilson RS (1983) New absorbable exoplants using gelatin and synthetic materials. Trans Am Ophthalmol Soc 81:966
102. Miller HA, Laroche M (1961) Les techniques du bourrelet scleral dans le décollement de la rétine. Bull Soc Ophtalmol Fr 61:946
103. Paufique L (1965) Technique de compression intra-sclerale. Mod Probl Ophthalmol 3:152
104. Spira C (1963) Report on two years of scleral inclusion. Presentation at third meeting of Club Jules Gonin, 1963. Cited in Cibis PA, Knobloch WH (1968) Scleral buckling procedures with preserved human sclera. In: McPherson A, Shelton JA, (eds) New and controversial aspects of retinal detachment. Harper & Row, New York, p 318

105. Knobloch WH, Cibis PA (1965) Retinal detachment surgery with preserved human sclera. Am J Ophthalmol 60:191
106. Thorpe H (1960) Fascia lata girdle. In: Schepens CL (ed) Importance of the vitreous body in retinal surgery with special emphasis on reoperations. Mosby-Year Book, St. Louis, p 211
107. Kloeti R (1962) Le fascia lata nouveau matériel en chirurgie retinienne. Bull Mem Soc Fr Ophtalmol 75:414
108. Havener WH, Olson RH (1962) Encircling fascia lata strips for retinal detachment. Arch Ophthalmol 67:721
109. Oshitari K, Hida T, Okada AA, Hirakata A (2003) Long-term complications of hydrogel buckles. Retina 23:257–261
110. Deutschmann (1913) Zur Heilung von Netzhautabloesung. Klin Monatsbl Augenheilkd 51:762
111. von Hippel E (1915) Erfolgreiche Operation bei posttraumatischer Netzhautabloesung. Klin Monatsbl Augenheilkd 55:146
112. Neubauer H (1963) Der amagnetische intraokulare Fremdkoerper. In Sautter H (ed) Entwicklung und Fortschritt in der Augenheilkunde, Ferdinand Enke, Stuttgart, p 292
113. Neubauer H (1965) Der intraoculare Fremdkoerper. Ber Dtsch Ophthalmol Ges 67:297
114. Cibis PA (1965) Vitreoretinal pathology and surgery in retinal detachment. Mosby-Year Book, St. Louis, pp 223–229
115. Kasner D (1969) Vitrectomy: a new approach to management of vitreous. Highlights Ophthalmol 11:304
116. Kasner D (1970) Vitrectomy. Highlights Ophthalmol 12:124
117. Kasner D (1969) The technique of radical anterior vitrectomy in vitreous loss. In: Welsh RC, Welsh J (eds) The new report on cataract surgery. Miami Education Press, Miami, p 1
118. Kasner D, Miller GR, Taylor WH, et al (1971) Surgical treatment of amyloidosis of the vitreous. Trans Am Acad Ophthalmol Otolaryngol 75:813
119. Machemer R, Buettner H, Norton EWD, Parel JM (1971) Vitrectomy: a pars plana approach. Trans Am Acad Ophthalmol Otolaryngol 75:813
120. Machemer R, Parel JM, Buettner H (1972) A new concept for vitreous surgery. I. Instrumentation. Am J Ophthalmol 73:1
121. Machemer R, Parel JM, Norton EWD (1972) Vitrectomy: a pars plana approach. Technical improvements and further results. Trans Am Acad Ophthalmol Otolaryngol 76:462

122. Parel JM, Machemer R, Aumayr W (1974) A new concept for vitreous surgery. 4. Improvements in instrumentation illumination. Am J Ophthalmol 76:6–12
123. Buettner H, Machemer R, Parel JM (1972) Vitrectomy. 1. Instrumentarium and operative technique. Ber Zusammenkunft Dtsch Ophthalmol Ges. 71:424–428
124. Machemer R, Parel JM, Buettner H (1972) A new concept for vitreous surgery. I. Instrumentation. Am J Ophthalmol 73:1–7
125. Machemer R, Parel JM, Buettner H, Parel JM (1972) Vitrectomy, a pars plana approach. Instrumentation. Mod Probl Ophthalmol 10:172–177
126. Machemer R, Norton EW (1972) Vitrectomy, a pars plana approach. II. Clinical experience. Mod Probl Ophthalmol 10: 178–185
127. Aaberg TM, Machemer R (1972) Vitreous band surgery. Instrumentation and technique. Arch Ophthalmol 87:542–544
128. Machemer R, Norton EW (1972) A new concept for vitreous surgery. 2. Surgical technique and complications. Am J Ophthalmol 74:1022–1033
129. Parel JM, Machemer R, Aumayr W (1974) A new concept for vitreous surgery. 5. An automated operating microscope. Am J Ophthalmol 77:161–168
130. Machemer R, Uffenorde T (1974) Hand support rail and surgical chair for microsurgery. Am J Ophthalmol 78:332–334
131. Machemer R (1974) Automated ophthalmoscopy hanger for operating room. Am J Ophthalmol 78:534
132. Machemer R (1974) A new concept for vitreous surgery. 7. Two instrument techniques in pars plan vitrectomy. Arch Ophthalmol 92:407–412
133. Machemer R (1976) Pars plana vitrectomy. Introduction. Trans Am Acad Ophthalmol Otolaryngol. 81:350–351
134. Machemer R (1976) Pars plana vitrectomy. Removal of preretinal membranes. Trans Am Acad Ophthalmol Otolaryngol 81:420–425
135. Peyman GA, Dodich NA (1971) Experimental vitrectomy. Instrumentation and surgical technique. Arch Ophthalmol 86:548–551
136. O'Malley C, Heintz RM (1975) Vitrectomy with an alternative instrument system. Ann Ophthalmol 7:585–594
137. Littmann H (1954) Ein neues Operations-Mikroskop. Klin Monatsbl Augenheilkd 24:473
138. Escoffery RF, Olk RJ, Grand MG, Boniuk I (1985) Vitrectomy without scleral buckling for primary rhegmatogenous retinal detachment. Am J Ophthalmol 99:275–281

139. Rosengren B (1938) Ueber die Behandlung der Netzhautabloesung mittelst Diathermie und Luftinjektion in den Glaskoerper. Acta Ophthalmol 16:3
140. Norton EW (1973) Intraocular gas in the management of selected retinal detachments. Ophthalmology 77:85
141. Vygantas CM, Meymen GA, Daily MJ, Ericson ES (1973) Octafluorocyclobutane and other gases for vitreous replacement. Arch Ophthalmol 90:235
142. Lincoff H, Maisel JM, Lincoff A (1984) Intravitreal disappearance rates of four perfluorocarbon gases. Arch Ophthalmol 102:928
143. Cibis PA, Becker B, Canaan S (1962) The use of liquid silicone in retinal detachment surgery. Arch Ophthalmol 68:590
144. Haut J, Ullern M, Boulard ML et al (1978) Utilisation du silicone intraoculaire apres vitrectomie comme traitement des retractions massive du vitre (note preliminaire). Bull Soc Ophtalmol Fr 78:361
145. Zivojnovic R (1987) Silicone oil in vitreoretinal surgery. Martinus Nijhoff/Dr W Junk Publishers, Dordrecht, The Netherlands
146. Parke DW 2nd, Aaberg TM (1984) Intraocular argon laser photocoagulation in the management of severe proliferative vitreoretinopathy. Am J Ophthalmol 97:434–443
147. Hueneke RL, Aaberg TM (1983) Instrumentation for continuous fluid-air exchange during vitreous surgery. Am J Ophthalmol 96:547–548
148. Haidt SJ, Clark LC, Ginsberg J (1982) Liquid perfluorocarbon replacement in the eye (abstr). Invest Ophthalmol Vis Sci 22[Suppl]:233
149. Chang S, Zimmerman NJ, Iwamoto T, et al (1987) Experimental vitreous replacement with perfluorotributylamine. Am J Ophthalmol 103:29
150. Chang S (1987) Low viscosity liquid fluorochemicals in vitreous surgery. Am J Ophthalmol 103:38