THE COMPLICATIONS OF PNEUMATIC RETINOPEXY*

BY *George F. Hilton,* MD, *Paul E. Tornambe,* MD (BY INVITATION), *Daniel A. Brinton,* MD (BY INVITATION), *Timothy P. Flood,* MD (BY INVITATION), *Stuart Green,* MD (BY INVITATION), *W. Sanderson Grizzard,* MD (BY INVITATION), *Mark E. Hammer,* MD (BY INVITATION), *Steven R. Leff,* MD (BY INVITATION), *Leo Mascuilli,* MD (BY INVITATION), *Craig M. Morgan,* MD (BY INVITATION), *David H. Orth,* MD (BY INVITATION), *Kirk H. Packo,* MD (BY INVITATION), *Lon S. Poliner,* MD (BY INVITATION), *Douglas L. Taren,* PhD (BY INVITATION), *James S. Tiedeman,* MD (BY INVITATION), AND (BY INVITATION) *David L. Yarian,* MD

INTRODUCTION

THE TERM "PNEUMATIC RETINOPEXY" WAS INTRODUCED AT THE AMERICAN Academy of Ophthalmology in 1985.[1] Since that time, through December 1989, there have been 101 papers, from seven countries, published on this new procedure. Included in these papers are 26 statistical series that are summarized in Table I.[1-18] Pneumatic retinopexy consists of transconjunctival injection of gas into the vitreous with cryotherapy or laser photocoagulation of the retinal breaks followed by postoperative positioning. Occasionally paracentesis is required if the central retinal

*From the University of California, San Francisco (Drs Hilton and Brinton), the University of California, San Diego (Drs Tornambe and Poliner), Rush University, Chicago (Drs Flood, Orth, and Packo), the University of Medicine and Dentistry of New Jersey, East Brunswick (Drs Green, Leff, Mascuilli and Yarian), the University of South Florida, Tampa (Drs Grizzard, Hammer and Taren), the University of Michigan, Ann Arbor (Dr Morgan), and Duke University, Durham (Dr Tiedeman).

TABLE I: STATISTICAL REPORTS ON PNEUMATIC RETINOPEXY, 1986-1989, ANATOMIC RESULTS AND TWO POSTOPERATIVE COMPLICATIONS

		NO (%) REATTACHED			
FIRST AUTHOR	NO EYES	ONE OPERATION*	REOPRATIONS (1157 EYES)	NO (%) NEW RETINAL BREAKS (933 EYES)	NO (%) PVR† (994 EYES)
Algvere[2]	35	29 (83%)	33 (94%)	4 (11%)	3 (8.6%)
Bovey[3]	27	18 (67%)	27 (100%)	8 (29%)	2 (7.4%)
Brinton[4]	70	57 (81%)	68 (97%)	11 (16%)	3 (4.3%)
Chan[18]	38	30 (79%)	38 (100%)	5 (13%)	0
Chen[5]	51	32 (63%)	—	11 (22%)	5 (9.8%)
Dominguez, 1986[6]	31	29 (94%)	30 (97%)	—	1 (3.2%)
Dominguez, 1987[7]	43	40 (93%)	42 (98%)	2 (5%)	1 (2.5%)
Friberg[4]	14	12 (86%)	14 (100%)	—	0 (0%)
Gnad[8]	27	24 (89%)	27 (100%)	1 (4%)	0 (0%)
Hilton, 1986[1]	20	18 (90%)	20 (100%)	2 (10%)	1 (5.0%)
Hilton, 1987[9]	100	84 (84%)	98 (98%)	7 (7%)	3 (3%)
Kelly[4]	268	217 (81%)	265 (99%)	—	—
Liggett[4]	30	16 (53%)	—	2 (7%)	1 (3.3%)
Lowe[10]	55	45 (82%)	54 (98%)	6 (11%)	3 (5.5%)
McAllister, 1987[11]	4	4 (100%)	4 (100%)	—	0 (0%)
McAllister, 1988[12]	56	40 (71%)	56 (100%)	11 (20%)	1 (1.8%)
Menchini[17]	36	31 (86%)	—	0	0
Mortensen[16]	12	10 (83%)	11 (92%)	—	1 (8.3%)
Packo[4]	33	27 (82%)	33 (100%)	9 (27%)	0 (0%)
Poliner[4]	39	24 (62%)	37 (95%)	3 (8%)	6 (15.3%)
Tornambe, 1989[13]	103	83 (81%)	102 (99%)	24 (23%)	3 (2.9%)
Tornambe, 1988[14]	34	28 (82%)	33 (97%)	4 (12%)	3 (8.8%)
Van Effenterre[15]	60	51 (85%)	59 (98%)	4 (7%)	1 (1.6%)
Vygantas[4]	12	8 (67%)	11 (92%)	—	—
Zakka[4]	20	16 (80%)	19 (95%)	2 (10%)	1 (5.0%)
Zegarra[4]	56	40 (71%)	56 (100%)	9 (16%)	1 (1.8%)
Total (%)	1274	1013 (80%)	1137 (98%)	125 (13%)	40 (4%)

*Some series included postoperative laser photocoagulation or cryotherapy.
†Postoperative proliferative vitreoretinopathy.

artery is temporarily closed. The complications of cryotherapy and laser photocoagulation are well known, therefore the emphasis of this paper will be a discussion of the prevention, or management if needed, of complications associated with gas injection and/or paracentesis.

MATERIALS AND METHODS

The material for the current paper was derived from three sources: (1) a detailed analysis of the complications listed in the Multicenter Randomized Controlled Clinical Trial comparing pneumatic retinopexy and scleral buckling (MCT),[13] (2) an analysis of the complications of pneumatic retinopexy reported in the literature from 1985 to 1989, and (3) a discussion of techniques to prevent potential complications based on the experience of the authors.

An attempt has been made to conduct a thorough search of the literature, but if some relevant papers have been overlook, we extend out apology to the authors.

RESULTS

The complications of pneumatic retinopexy experienced during the multicenter clinical trial (MCT) have been previously published in the form of a list.[13] Table II provides additional details regarding corrective action, preoperative and postoperative visual acuity and the anatomic results of each eye that experienced one or more complications. Further details on the complication of new/missed retinal breaks is not included in Table II because it has been previously published in considerable detail.[13]

The complications that have been published in the literature, but which were not seen during the MCT are tabulated in Table III.[1,2,5,9,12,14,15,19,20] The complications of pneumatic retinopexy that have not been observed with scleral buckling are listed in Table IV.[1,4,9,21,22] The complications of scleral buckling that have not been reported with pneumatic retinopexy are listed in Table V.[23,24]

DISCUSSION

Most of the 26 published series on pneumatic retinopexy listed in Table I are reports from surgeons going through the "learning curve." Despite the fact that the quality of these papers is quite variable, no attempt has been made to eliminate any publications. With only a few exceptions, the published series have rather similar results with 80% of the 1274 eyes

TABLE II: THE COMPLICATIONS OF PNEUMATIC RETINOPEXY
MCT COMPARING PNEUMATIC RETNOPEXY AND SCLERAL BUCKLING[13] (198 EYES)

NO	COMPLICATIONS (BREAKS OMITTED*)	CORRECTIVE ACTION	VISUAL ACUITY		REATTACHED	
			PREOPERATIVE	POSTOPERATIVE†	1 OPERATION	REOPERATION
1	Break reopen, ERM	Buckle	20/30	20/30		+
2	ERM	None	20/40	20/20	+	
3	Pars plana gas	Evacuate, reinject	20/25	20/40	+	
4	Vitreous hemorrhage	None	20/30	20/40	+	
5	Break reopen	Repeat PR	20/20	20/20		+
6	Break reopen, choroid detachment	Buckle	20/25	20/30		+
7	Break reopen, new break	Cryo	20/30	20/40		+
8	Vit incarc	None	20/30	20/20		+
9	Vit incarc	None	20/30	20/25	+	
10	Choroid detachment, new break	Cryo	20/25	20/25		+
11	Malignant glaucoma	Paracentesis	20/20	20/20	+	
12	PVR-C2, choroid detachment	Buckle	CF	20/160		+
13	Choroid detachment	None	20/60	20/50		+
14	Peripheral subretinal hemorrhage	None	CF	20/25	+	

TABLE III: PUBLISHED COMPLICATIONS NOT SEEN IN THE MULTICENTER TRIAL

COMPLICATIONS	FIRST AUTHOR	NO. OF EYES	MANAGEMENT	RESULT
Operative				
Vitreous loss	Friberg[19]	3	Cotton-tipped applicator	Good
Subconjunctival gas	Hilton[9]	2	None	Good
Shift of SRF into macula	Yeo[20]	1	None	Good
	McAllister[12]	1	None	Good
Enlargement of break	McAllister[12]	2	None	Good
Postoperative				
Shift of SRF to flat break	Chen[5]	1	*	*
	Tornambe[14]	1	Cryo	Good
Delayed SRF reabsorption	Chen[5]	3	*	*
	McAllister[12]	2	None	Good
	Chan[18]	6	Gas injection	Reduced vision
Macular pucker	Chen[5]	1	None	*
	Algvere[2]	2	*	*
	McAllister[12]	1	*	*
Increase of vitreous pigment	Hilton[1]	13	None	Good
Symptomatic vitreous floater	Hilton[9]	3	None	Good
Neck pain	Hilton[1]	2	Heating pad	Good
Subretinal pigment, extrafoveal	Hilton[9]	1	None	Good
Vitreous haze, 3-8 days	Van Effenterre[15]	6	None	Good

*Management and/or result not given in publication.

TABLE II: THE COMPLICATIONS OF PNEUMATIC RETINOPEXY
MCT COMPARING PNEUMATIC RETNOPEXY AND SCLERAL BUCKLING[13] (198 EYES) (CONT'D)

NO	COMPLICATIONS (BREAKS OMITTED*)	CORRECTIVE ACTION	VISUAL ACUITY		REATTACHED	
			PREOPERATIVE	POSTOPERATIVE†	1 OPERATION	REOPERATION
15	Lens touch, hyphema	None	CF	20/40	+	
16	Macular hole	None	CF	20/125	+	
17	ERM	None	20/400	20/60	+	
18	PVR-C1	Vitrectomy	HM	20/40		+
19	Break never closed	Buckle	HM	20/60		+
20	Pars plana gas, ERM, new break	Evacuate, reinject	HM	20/25		+
21	ERM	None	HM	20/50	+	
22	Break reopen	Buckle	CF	20/40		+
23	Subretinal gas	None	20/80	20/40	+	
24	PSC cataract, new break	Cat: None Bk: Cryo	20/80	20/25		+
25	Subretinal gas	None	20/400	20/80	+	
26	Endophthalmitis, new break, choroid detachment	Buckle	LP	HM	0	0
	PVR-D2	Vitrectomy				
27	Uveitis (mild)	None	20/20	20/20	+	

*For a detailed report on new/missed retinal breaks refer to reference 13.
†Measured with a "masked" method.
CF, counting fingers; ERM, macular epiretinal membrane, minimal; HM, hand movements; LP, light perception; PR, pneumatic retinopexy; PSC, posterior subcapsular cataract, trace; PVR-C1, proliferative vitreoretinopathy, grade C1; Vit incarc, incarceration of vitreous in paracentesis wound; MCT, Multicenter Controlled Clinical Trial.

reattached with the initial pneumatic procedure. Ninety-eight percent of all eyes were reattached with reoperations and only three series were below 95% for the final cure rate. Many of these authors immediately resorted to a traditional scleral buckling procedure for any pneumatic retinopexy failures. However, it has been subsequently learned that many of the initial failures can be cured with an office procedure such as repeat gas injection, or supplemental cryo/laser, or with modification of the head position.

Four percent of the total developed various degrees of postoperative proliferative vitreoretinopathy (PVR) (Table I). This is similar to the 5% PVR found in the scleral buckling control group in the MCT.[13]

TABLE IV: COMPLICATIONS OF PNEUMATIC RETINOPEXY THAT HAVE NOT BEEN OBSERVED WITH SCLERAL BUCKLING (BASED ON 101 PAPERS ON PNEUMATIC RETINOPEXY)

Subconjunctival gas[9]
Gas entrapment at the pars plana[4,22]
Subretinal gas[21]
Neck pain[1]

TABLE V: COMPLICATIONS OF SCLERAL BUCKLING THAT HAVE NOT BEEN REPORTED WITH PNEUMATIC RETINOPEXY[23,24]

Avulsion of extraocular muscle	Hemorrhage, choroidal
Blepharoptosis	Hypotony
Chemosis	Infection, extraocular
Corneal problems	Incarceration of retina
Conjunctival cysts	Intraocular lens dislocation
Conjunctival tearing	Mydriasis, permanent
Central retinal artery occlusion	Necrosis, anterior segment
Cystoid macular edema	Pain, severe
Diplopia	Perforation of retina
Exposure of buckle	Pigment "fall out," macular
Extrusion of buckle	Proptosis
Erosion of sclera, choroid, and retina	Rupture of globe
Enophthalmos	Retinal detachment, exudative
Fish mouthing phenomenon	Suture granuloma
Glaucoma, open-angle	Strabismus
Glaucoma, angle-closure	Scleral laceration
General anesthetic problems	Scleral perforation
Hemorrhage, subconjunctival, late, recurrent	Symblepharon
	Tenon's capsule exposure
Hemorrhage, subretinal, macular	Uveitis, severe
Hemorrhage, vitreous, massive	Vortex vein damage

The eyes with complications listed in Table II were, with one exception, all reattached. Approximately half of these eyes required no corrective action. Of those requiring additional surgery, three were managed with cryotherapy, one with repeat pneumatic retinopexy, five were managed with scleral buckling, and two with vitrectomy.

The complications noted in Table III were generally self limited. Only four reported any corrective action. The results were generally satisfactory except for macular pucker, loculated subretinal fluid in the macula, and shifting subretinal fluid into a flat inferior retinal break.

Pneumatic retinopexy differs from traditional scleral buckling in that the following procedures are not required: conjunctival peritomy, removal of corneal epithelium, exposure of the extraocular muscles, tenotomy of the extraocular muscles, choroidotomy, dissection of scleral flaps, suturing and placement of the scleral buckling material. Therefore, it is not surprising that 41 complications of scleral buckling, as noted in Table V, have not yet been reported in association with pneumatic retinopexy. Some of the complications of scleral buckling that are potential problems in pneumatic retinopexy, that have not yet been reported, include central retinal artery occlusion, open angle glaucoma, angle closure glaucoma, hemorrhagic detachment of choroid, exudative retinal detachment and severe uveitis.

Most of the complications of pneumatic retinopexy can be prevented by careful preoperative examination, special attention to surgical details and appropriate postoperative management. The methods for prevention, or management if needed, will be considered in alphabetical order.

CATARACT

There was one reported case of anterior lens touch during paracentesis (Table II). This can be prevented if the surgeon always directs the paracentesis needle over iris. The one reported case required no corrective action and the limited opacity was not progressive during 6 months of follow-up.

CHOROIDAL DETACHMENT

There were 3 eyes with postoperative choroidal detachment in the MCT compared to 16 in the scleral buckling control group (Table II). This difference was statistically significant ($P < 0.001$). None of these choroidal detachments caused angle closure. The cause of choriodal detachment in pneumatic retinopexy is not known. None of the cases required corrective action and the detachments resolved spontaneously. A severe detachment might require posterior sclerotomy and injection of balanced salt solution into the vitreous.

DELAYED REABSORPTION OF THE SUBRETINAL FLUID

This phenomenon has taken two forms. One is the persistence of subretinal fluid inferiorly and it typically clears after 1 or 2 months. Another is a specific entity in which small (1 to 3 disc diameters) pockets of loculated subretinal fluid persist for several months.[18] There are no associated retinal breaks. No specific management is required but one persistent case in the posterior pole resolved after a "light grid pattern" of argon laser photocoagulation.[4] These pockets of fluid have also been reported after scleral buckling, and occasionally have a clinical appearance that simulates serous detachment of the retinal pigment epithelium.[25] They have also been seen in experimental animals managed with scleral buckling.[26]

ENDOPHTHALMITIS

There have been two cases of this serious complication.[13,27] This also rarely occurs with scleral buckling.[28] This potential problem can usually be prevented by the application of several drops of Betadine solution® (10% povidone-iodine) to the cornea and conjunctiva for 3 minutes prior to injection. This prophylactic use of iodine was not used in the recommended manner in these two cases. There have not yet been any reported cases in eyes that have been prepared with the Betadine solution®.

GAS ENTRAPMENT BETWEEN THE PARS PLANA AND THE LENS

Inadvertent injection of gas adjacent to the pars plana epithelium (into the Canal of Petit) can generally be avoided by passing the needle deep into the vitreous cavity, approximately 7 mm. Then the needle is partially withdrawn so that only 2 mm of the tip remain in the vitreous and then the injected gas will pass into the vitreous. If gas should be trapped in this anterior position, it can be evacuated with a 27 gauge needle mounted on a 3 ml syringe. The supine patient's head is oriented to the side so that the gas bubble is uppermost. The plunger of the syringe is removed and the syringe is half filled with balanced salt solution. As the needle passes through the sclera and pars plana and enters the gas bubble the surgeon will observe the escaping gas bubbling up through the fluid in the syringe. In this way one may know that the tip of the needle has entered the gas pocket. After the missplaced gas has been evacuated another bubble of gas can be injected deeper into the vitreous. An alternative is to orient the patient face down for 24 hours. The gas bubble will usually break through the anterior hyaloid face and pass back to the posterior pole. Thereafter the patient can be oriented with the retinal break uppermost.

GAS, SUBCONJUNCTIVAL

There have been three cases of this minor complication due to the minimal escape of gas from the eye into the subconjunctival space (Table III). This was not clinically significant and no corrective action was required. Subconjunctival gas can be prevented by immediate closure of the needle track as the needle is removed from the eye. This is accomplished by placing a cotton-tipped applicator on the conjunctiva adjacent to the needle shaft. A moderate degree of rotary torque is applied to the applicator so that it immediately rolls into position to close the needle track as the needle is removed. With the applicator firmly in place, the patient's head is then rolled to the opposite side and the gas bubble moves away from the needle track and there is no further risk of escape of gas into the subconjunctival space.

GAS, SUBRETINAL

All reported cases of this complication were due to the introduction of multiple small bubbles into the vitreous cavity.[21] The eyes were positioned with the retinal break uppermost, allowing one or more small bubbles to enter the subretinal space. This can be prevented by injecting a single large gas bubble.

The patient should be in a supine position with the head rotated 45 degrees to one side. The injection is made 4 mm posterior to the limbus with a one-half inch 30 gauge needle. The syringe is vertical with reference to the tangent at the injection site and with reference to the floor. Approximately 2 mm of the needle should be in the vitreous cavity at the time of injection. This will produce one gas bubble at the needle tip. If one should inadvertently introduce many small gas bubbles, "fish eggs," these can generally be made to coalesce by placing the patient has previously described, in a supine position and the head rotated 45 degrees to one side. This will place all of the bubbles at the uppermost portion of the pars plana. One or two flicks with the index finger against the conjunctiva overlaying the uppermost pars plana will generally break down the surface tension of the multiple small bubbles and produce one single bubble. The finger flick method is usually successful, but if the small bubbles persist, the patient's head should be oriented with the bubbles away from the retina break and they will spontaneously coalesce into one large bubble within 24 hours. Thereafter the patient can be positioned with the retinal break uppermost.

The two cases of subretinal gas in the MCT were rather small bubbles and required no corrective action. However, large volumes of subretinal gas must be removed. This can usually be done by positioning the patient with the retinal break inferiorly, utilizing massage with the scleral depressor, thereby causing the gas to reenter the vitreous cavity. If this fails, the gas must be removed by aspiration.

GLAUCOMA, MALIGNANT

There has been one case of malignant glaucoma in an aphakic eye (Table II). The patient did not follow instructions and slept on his back with his face up. The gas bubble caused blockage at the plane of the ciliary body with posterior diversion of aqueous. The case responded well to paracentesis and face down positioning. The retina was reattached with postoperative visual acuity of 20/20. This rare complication can be prevented by avoiding a face up position. Of course, face up positioning for just a few minutes is well tolerated and may be utilized for the instillation of eye drops.

HEMORRHAGE, SUBRETINAL, PERIPHERAL

The one reported case was probably due to movement of the unthawed cryo probe causing fracturing of the frozen blood vessels (Table II). This patient did well with reattachment of the retina and the preoperative vision of 20/200 improved postoperatively to 20/40. This is preventable by not moving the cryo probe until the white ice ball in the fundus has completely disappeared.

HEMORRHAGE, VITREOUS

The one case of mild vitreous hemorrhage settled to the 6 o'clock position by the first postoperative day and caused no symptoms (Table II). The retina was reattached and the patient's postoperative visual acuity was 20/20. This complication can be minimized by avoiding the horizontal and vertical meridians where the anterior ciliary arteries may be inadvertently damaged with the needle.

IRIS INCARCERATION

This complication can be prevented by the use of a very small paracentesis instrument, such as a 30 gauge needle. Surgical knifes are too large and are therefore contraindicated.

LENS TOUCH

The one reported case of anterior lens touch could have been prevented if the tip of the paracentesis needle had been directed over iris, not over the anterior lens capsule (Table II).

MACULAR HOLE

This complication may occur after various types of retinal surgery, including both scleral buckling and pneumatic retinopexy. Indeed, it most often occurs without surgical intervention. There is no known method for prevention. A possible surgical technique for macular hole was presented at the American Academy of Ophthalmology in 1989.[29] This technique utilizes standard vitrectomy plus the removal of premacular vitreous cortex with suction through the Soft-Tip Needle (Grieshaber), fluid-gas exchange and face down positioning.

MACULAR PUCKER

As noted in Table III, there were several reported cases of macular pucker but the visual results were not published. In the MCT there were four cases of mild preretinal macular gliosis, but through 6 months of follow-up these eyes remained free of visual symptoms. There is no known method for preventing this complication. In severe cases, the epiretinal membrane can be removed by vitreous surgery techniques.

NECK PAIN

The two cases of reported neck pain were caused by postoperative head tilt without support (Table III). This can be prevented if the patient will support the tilted head with the hand, resting the elbow on the arm of an armchair. This relatively minor problem can be managed with analgesics, muscle relaxants, and a heating pad.

PIGMENT, SUBRETINAL

This complication occurs with both scleral buckling and pneumatic retinopexy and is correlated with the amount of cryotherapy.[30] Occasionally it will make a rather specular fundus appearance but has no significant effect on retinal function.

PIGMENT, VITREAL

This common finding, "tobacco dust," is seen preoperatively in the majority of eyes with retinal detachment. After cryotherapy, with either a buckle or bubble, there may be an increase in the amount of vitreal pigment. This can be minimized by minimizing the number and intensity of cryo applications.[30]

PROLIFERATIVE VITREORETINOPATHY

This serious complication was found postoperatively in three eyes (3%) in the MCT compared to 5% in the scleral buckling control group.[13] One of these occurred in association with the one case of endophthalmitis. The other two were grades C1 and C2 and were both successfully reattached, one with scleral buckling and the other with vitrectomy.[31] There is no known method to prevent this complication but it is correlated with the dispersal of viable retinal pigment epithelial cells onto the surfaces of the retina and vitreous. Pigment cell dispersion can be minimized by the use of laser photocoagulation after the retina has been pneumatically reattached, rather than cryotherapy while the retina is still detached. Whether delayed laser photocoagulation, rather than immediate cryotherapy, will actually reduce the incidence of PVR is one of the questions being studied in the new multicenter randomized controlled clinical trail, The Pneumatic Retinopexy Trial II.

REFRACTIVE CHANGE

Three percent of eyes in the MCT developed a myopic shift of 1 diopter or more compared to 68% in the scleral buckling control group.[13] The well known problem of post-buckling myopia has been correlated with increased axial length but the cause of the few cases managed with the pneumatic procedure is not known. Perhaps there was an inappropriate increase of nuclear sclerosis during the 6 months of follow-up.

RETINAL BREAKS, MISSED

In addition to the definite phenomenon of new postoperative breaks, there are occasions where the surgeon may overlook a break preoperatively. This problem can be minimized by a very meticulous preoperative examination of the retina with binocular indirect ophthalmoscopy and scleral indentation, supplemented with slit lamp biomicroscopy when indicated.

REINTAL BREAKS, NEVER CLOSED

This complication has been reported in just one case (Table II). The surgeon did not provide adequate detail to indicate the cause.

RETINAL BREAKS, NEW

As noted in Table I, the incidence of new/missed retinal breaks in the literature is 13%. This is comparable to reports in the literature of new breaks after scleral buckling with an incidence of 21%, 8%, 4%, 17%, and

18%.[12,32-35] The MCT revealed that 59% of such breaks appeared within the first month after pneumatic retinopexy.[13] These breaks were more frequent in aphakic/pseudophakic eyes. With appropriate management 96% of the eyes with new breaks were reattached and 83% obtained postoperative visual acuity of 20/50 or better.[13] Thirty-three percent of eyes with new breaks were satisfactorily managed with cryo or laser only, 33% required a repeat gas injection, 46% were reattached with a scleral buckling procedure and one eye (4%) was managed with a vitrectomy. There is no known method for preventing new retinal breaks, but The Pneumatic Retinopexy Trial II is evaluating the possible value of scatter photocoagulation between the ora serrata and the equator in aphakic/pseudophakic eyes as a possible means to reduce this complication.

RETINAL BREAKS, REOPENED

In the MCT there were five breaks which reopened, three during the first week and two reopened during the second month (Table II). The early cases were due to either improper postoperative positioning of the head or inadequate volume of gas. A minimum volume for injection should be 0.3 ml of C3F8 or 0.5 ml of SF6 for a break which is 1 clock hour. The breaks which reopened in the second month were probably due to an inadequate margin of cryotherapy. It is recommended that a rather broad area of cryo/laser treatment should extend approximately 2 disc diameters beyond the break edge.

SHIFTING OF SUBRETINAL FLUID INTO THE MACULA OR INTO A RETINAL BREAK IN FLAT RETINA

This problem was not encountered in the MCT but four cases have been reported in the literature.[5,12,14,20] The result in one case was not published, the other three had satisfactory results. This rare event can be prevented by the use of the "steam roller maneuver."[9] In this maneuver the seated patient is placed in a face down position immediately after the gas injection. The head is then slowly turned during 10 to 15 minutes, moving the head so that the gas bubble will "steam roller" or "squeegee" the subretinal fluid through the retinal break back into the vitreous cavity. This greatly reduces the volume of subretinal fluid. Then the patient can be positioned with retinal break uppermost without fear of shifting fluid into the macula or into a flat break.

UVEITIS

Two surgeons have mentioned this complication. In one case it was a mild iritis which required no treatment and it cleared spontaneously within 3 weeks.[13] The other was a mention of six eyes that exhibited the vitreous haze for 3 to 8 days.[15] No specific treatment was utilized and a satisfactory resulted was noted. Intraocular inflammation has been previously reported with gas injections in laboratory animals but clinical uveitis with pneumatic retinopexy has been very minimal.

VITREOUS INCARCERATION IN THE PARACENTESIS SITE

This complication is preventable if one avoids paracentesis in an aphakic eye, or an eye in which there is an open capsule such that formed vitreous could enter the anterior chamber. In such cases is is preferable to do paracentesis through the pars plana with the removal of fluid vitreous. Or, in an aphakic eye, it is an easy matter to direct the pars plana needle through the pupil into the anterior chamber and remove aqueous.

VITREOUS LOSS

One surgeon noted three cases in which a small bead of formed vitreous was noted at the needle track, but with a change of technique that has not happened again.[19] The possibility of this complication is prevented in the same way as the prevention of subconjunctival gas as described above.

With careful attention to detail most complications of pneumatic retinopexy can be prevented and most of the unpreventable complications can be satisfactorily managed. As with traditional scleral buckling, the major problem is still PVR. Perhaps the most troublesome complication is that of new retinal breaks. These can generally be satisfactorily managed with good visual and anatomic results but extra effort is required.

SUMMARY

There have been 26 published series with a total of 1274 detachments operated with pneumatic retinopexy. Eighty percent were reattached with a single procedure and 98% with reoperations. New breaks occurred in 13% and PVR in 4%. The complications published in 101 papers on pneumatic retinopexy in the last 5 years are analyzed as to frequency, prevention, management, and results.

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DISCUSSION

Dr Dennis M. Robertson. Doctor Hilton has reviewed with us the complications of pneumatic retinopexy and he has offered suggestions to help minimize the severity and frequency of these complications. Whereas some of the complications of pneumatic retinopexy are preventable, as has been suggested by Doctor Hilton, there are a number of problems that cannot be eliminated. I will briefly comment on several of these problems. One problem relates to the need for careful selection of the type of retinal detachment that is suitable for pneumatic retinopexy. Generally recognized exclusion criteria, for example, include inferiorly located breaks, breaks larger than 1 clock hour size, severe glaucoma, and significant vitreoretinal proliferation. Other relative exclusion factors are the presence of aphakia or pseudophakia with an absent or ruptured posterior capsule.

An additional problem relates to the need for positioning aged patients. Doctor Hilton has previously stated that one of the major disadvantages of pneumatic retinopexy relates to postoperative positioning. Patients not only must have sufficient intelligence to adhere to the positioning requirements, but they must have an appropriate physical capacity to endure the positioning.

Another problem relates to violation of the vitreous cavity itself. Following gas injection there is increased protein and cells in the vitreous. Whether this is a minor problem or a problem with significant complications is uncertain. Nevertheless, injection into the vitreous cavity does disturb the tissue. If a simple disturbance of the vitreous body is not a problem, certainly mechanical traction exerted by an expanding gas bubble in the vitreous cavity poses a potential problem for increased vitreoretinal traction and retinal tear formation. An additional complication can occur if gas is injected into the previtreal spaces; this allows the potential complication of retinal dialysis, lens dislocation, and/or cataract.

Additionally, there are problems with mountain and air travel postoperatively because of expansion of the intraocular gas. The first reference to this that I am aware of was 14 years ago in a report by Norton and Fuller (*Advances in Vitreous Surgery*. Springfield, Charles C Thomas, 1976, pp 535-542). Fuller referred to this problem again in a Letter to the Editor in the *American Journal of Ophthalmology* in 1981. He suggested that it was safe to fly in an airplane if the intraocular gas was a third of the volume of the vitreous cavity or less, but he recommended giving such patients Diamox 2 hours before flying. In 1980, Brinkley reported that a patient experienced pain in the eye with intraocular gas when the cabin pressure of a commercial airplane approached an atmospheric pressure equivalent to 7000 feet above sea level. The pain disappeared when the cabin pressure was increased as the airplane descended to an elevation of 550 feet. More recently, Hanscom and Diddie reported ocular pressure complications in a patient who traveled in a motor vehicle from sea level to 4289 feet over an interval of 20 minutes. Although these problems are unlikely to occur with volumes of gas that are typically used for pneumatic retinopexy, the potential complication of an acute rise in the intraocular pressure is not trivial. In a 1976 publication by Aronowitz and Brubaker (*Arch Ophthalmol* 1976; 94:1191-1196), the authors reported the effects of intraocular gas on intraocular pressure with varying volumes of gas and varying atmospheric pressures. Their calculations suggested that in the human eye, a volume of 1/4 ml of gas would expand to raise the intraocular pressure several millimeters if a person were to ascend in an elevator to an altitude of approximately 500 feet. In the circumstance where a patient ascended in a commercial airplane from near sea level to 8000 feet or higher (commercial aircraft are not pressurized below 2400 meters or 8000 feet), a 1/4 ml of gas would cause the intraocular pressure to rise up to 40 or 50 mm of mercury. Although this potential complication related to a rapidly expanding as is common to any procedure utilizing intraocular gas, it nevertheless is an inherent potential complication for every case of pneumatic retinopexy.

An additional problem relates to delayed absorption of subretinal fluid. Pneumatic retinopexy will not decrease the frequency of this problem but will, likely, increase it. For example, 8 of 38 eyes reported by Chan and Wessels showed a delay of subretinal fluid absorption.

A greater problem relates to an increased incidence of retinal breaks following pneumatic retinopexy. In a retrospective study of 56 cases reported by McAllister in which the incidence of retinal breaks following treatment by pneumatic retinopexy was compared with the same complication following treatment using either a Lincoff balloon or scleral buckling, the incidence of new break formation was 20% with pneumatic retinopexy, 18% with a Lincoff balloon, and 1.3% with scleral buckling. It is noteworthy that in Hilton's first report published in 1987 there was a 7% incidence of new breaks, whereas in the multicenter randomized controlled clinical trial in which he was a participant, the incidence of new breaks was 23%. Why was the first report on pneumatic retinopexy associated with only a 7% incidence of new breaks whereas the randomized study demonstrated a 23% incidence of new breaks? Which figure is more representative? In the randomized study, the incidence of retinal breaks after scleral buckling was reported as 13%, which is far greater than the 3% incidence of new breaks reported in a 1981 publication by Hilton and colleagues. Perhaps the reason the incidence of retinal breaks associated with scleral buckling in the randomized study was so much higher than other published reports is that 67% of the eyes developing new breaks in the scleral buckling group also had had an intravitreal injection. These figures appear to support the view that injection of gas into the vitreous cavity is associated with a high complication rate of new break formation. This troublesome complication probably occurs because gas displaces vitreoretinal traction bands, thereby causing further traction on the retina with the complication of a new retinal tear.

Finally, another problem of pneumatic retinopexy appears to be the increased chance for reoperation. Since the effects of vitreous traction cannot be eliminated by pneumatic retinopexy, and since vitreous traction is the primary culprit in the development of tears and subsequent retinal detachment, it is understandable that the retinal detachment may persist or recur. Such problems cause additional expense and time delay before the patient is able to resume full activities. In my view, selected patients can be more safely and quickly allowed to resume activities with an outpatient scleral buckling procedure done under local anesthesia.

Doctor Hilton continues to help us better understand how to anticipate and minimize the complications associated with pneumatic retinopexy. Although there appears to be an indication for using pneumatic retinopexy in the management of selected retinal detachment cases, because of the complications associated with new tear formation and because of the relatively high rate of reoperation following a failed first procedure, I tend to regard the procedure as tentative rather than definitive.

Dr C. P. Wilkinson. I would like to congratulate Doctor Hilton for both a nice paper, and perhaps more importantly, for making all of us reevaluate the methods which we employ in managing patients with primary retinal detachments.

I would like to expand upon Doctor Robertson's excellent discussion regarding the primary failure rate. In my opinion this is the most important complication of this procedure. In these days of "outcome assessment" we do need to look very, very closely at how many of these eyes require a second operation. It may be psychologically harder for me than for the patient, but I have great difficulty in requiring these people to return for additional surgery. In the pneumatic retinopexy collaborative study demonstrated on the slide, "Center a" had approximately a 75% success rate, both with buckling and pneumatic retinopexy, following one procedure. In evaluating one-operation similar results from the remaining centers there is essentially a 20% difference between pneumatic retinopexy and buckling, the latter being more effective. I think most of us who continue to employ scleral buckling believe that we should be able to cure at least 90% of these cases with one operation. It appears, therefore, that we might be reoperating on 10% to 20% more eyes if we do a pneumatic procedure than if we do our standard buckle.

My questions for Doctor Hilton are: (1) "what factors are responsible for this frighteningly high primary anatomical failure rate? and (2) how can this rate be reduced?

DR GEORGE HILTON. I would like to thank the discussants for their very helpful comments. I agree with Doctor Robertson that this is not an operation for all eyes, but cases must be carefully selected. In my practice, I think about 25% of all detachments seem to lend themselves to this approach. The package he mentioned of careful selection and postoperative positioning is absolutely true.

Regarding air travel, this may be one of the main reasons why we stopped using C3F8. We now just use SF6 where the bubble disappears within about 1 week or 10 days. So they are not delayed as long as with the longer acting gases.

Both of the discussants were concerned about the incidence of new retinal breaks. We have found them relatively easy to manage and we have come to feel that it's probably a price worth paying for the advantages of this outpatient procedure with this relatively low morbidity and lack of hospitalization. But the major advantage is the matter of vision. In the study referred to it was noted that the final postoperative visual acuity was better in the eyes treated with pneumatic retinopexy than those managed with scleral buckling. This will be reported at the Academy this year and still seems to be true after 2 years of follow-up. We would feel that the nuisance of managing additional interventions is the price that is probably worth paying to get the advantages of no hospitalization, decreased morbidity and postoperative visual acuity that is better than the control group managed with scleral buckling.