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The Pneumatic Retinopexy versus Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial (PIVOT)

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Purpose: The optimal surgery to repair rhegmatogenous retinal detachment (RRD) is unknown. The purpose of this trial was to compare outcomes of pneumatic retinopexy (PnR) versus pars plana vitrectomy (PPV) for the management of primary RRD.

Design: Prospective, randomized controlled trial.

Participants: Patients with RRD demonstrating a single retinal break or a group of breaks in detached retina within 1 clock hour above the 8- and 4-o'clock meridians, with any number, location and size of retinal breaks or lattice degeneration in attached retina.

Methods: Patients were randomized to undergo either PnR or PPV. Macula-on and macula-off patients were assigned to intervention group by stratified randomization and were treated within 24 and 72 hours, respectively.

Main Outcome Measures: The primary outcome was 1-year Early Treatment Diabetic Retinopathy Study (ETDRS) visual acuity (VA). Important secondary outcomes were subjective visual function (25-item National Eye Institute Visual Function Questionnaire), metamorphopsia score (M-CHARTS), and primary anatomic success.

Results: One hundred seventy-six patients were recruited between August 2012 and May 2016. ETDRS VA after PnR exceeded that after PPV by 4.9 letters at 12 months (79.9±10.4 letters vs. 75.0±15.2 letters; $P = 0.024$). Mean ETDRS VA also was superior for the PnR group compared with the PPV group at 3 months (78.4±12.3 letters vs. 68.5±17.8 letters) and 6 months (79.2±11.1 letters vs. 68.6±17.2 letters). Composite 25-item National Eye Institute Visual Function Questionnaire scores were superior for PnR at 3 and 6 months. Vertical metamorphopsia scores were superior for the PnR group compared with the PPV group at 12 months (0.14±0.29 vs. 0.28±0.42; $P = 0.026$). Primary anatomic success at 12 months was achieved by 80.8% of patients undergoing PnR versus 93.2% undergoing PPV ($P = 0.045$), with 98.7% and 98.6%, respectively, achieving secondary anatomic success. Sixty-five percent of phakic patients in the PPV arm underwent cataract surgery in the study eye before 12 months versus 16% in the PnR group ($P < 0.001$).

Conclusions: Pneumatic retinopexy should be considered the first line treatment for RRD in patients fulfilling (PIVOT) Pneumatic Retinopexy versus Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial (PIVOT) recruitment criteria. Pneumatic retinopexy offers superior VA, less vertical metamorphopsia, and reduced morbidity when compared with PPV. *Ophthalmology 2018;■:1–9 © 2018 by the American Academy of Ophthalmology*

Supplemental material available at www.aaojournal.org.

Although certain clinical scenarios may dictate a particular surgical approach over another, the optimal surgical technique for the management of many common configurations of uncomplicated rhegmatogenous retinal detachment (RRD) remains controversial. Pneumatic retinopexy (PnR) was described first by Hilton and Grizzard[1] more than 30 years ago as a "two-step outpatient operation without conjunctival incision." Until then, the mainstay of surgery for RRD repair had been scleral buckling (SB). The relative simplicity, favorable anatomic success rates, and low complication profile led the authors to advocate use of PnR in selected RRD cases. A subsequent prospective, multicenter, randomized controlled trial comparing PnR with SB for RRD demonstrated superior visual acuity (VA) with PnR at 6 months and 2 years after surgery, including in those patients whose primary PnR had failed, with no significant difference in primary success rates.[2,3]

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The introduction and refinement of pars plana vitrectomy (PPV) techniques have revolutionized the management of RRD. Pars plana vitrectomy now represents the most commonly performed intervention for RRD in most parts of the world.[4] A prospective, multicenter randomized controlled trial compared SB versus PPV and reported single-operation success of 63.6% and 63.8% for SB and PPV, respectively, in phakic patients ($P = 0.97$) and 53.4% and 72%, respectively, in pseudophakic patients ($P = 0.002$).[5]

Despite the current popularity of PPV globally, the relative simplicity and elegance of PnR remains appealing. Put plainly, the procedure involves the application of retinopexy to the retinal break (cryotherapy or laser) before or after injection of expansile gas. The purpose of this trial was to compare the functional and anatomic outcomes of PnR versus PPV for the management of primary RRD.

Methods

Study Design

This was a prospective randomized controlled trial comparing 2 surgical interventions (PnR vs. PPV) for the management of primary RRD performed at St. Michael's Hospital, Toronto, Canada, after obtaining research ethics board approval. The described research adhered to the tenets of the Declaration of Helsinki. The trial was registered at ClinicalTrials.gov (identifier, NCT01639209).

Participants

Participants provided written and informed consent. Consecutive eligible adults with RRD were offered participation in the trial. The inclusion and exclusion criteria are listed in Figure 1.

Randomization and Masking

Block randomization (block size, 4) took place in a stratified manner according to macular status at presentation. Randomization.com was used to create the randomization list and was uploaded to Research Electronic Data Capture (REDCap) (www.project-redcap.org). Patients were introduced to the study by one of the trial clinical investigators (A.R.B., D.T.W., F.A., L.R.G., R.H.M., R.J.H.) or a trainee working under their supervision. If a patient was interested in learning more about the PIVOT study, they were referred to the study coordinator (not part of the clinical care team) who carried out a detailed informed consent and enrollment process. As soon as a patient was enrolled in the study, the study coordinator accessed the REDCap website and entered the study identification and macular status. REDCap then displayed the treatment group assignment to the study coordinator. The study coordinator then informed the recruiting physicians (A.R.B., D.T.W., F.A., L.R.G., R.H.M., R.J.H.).

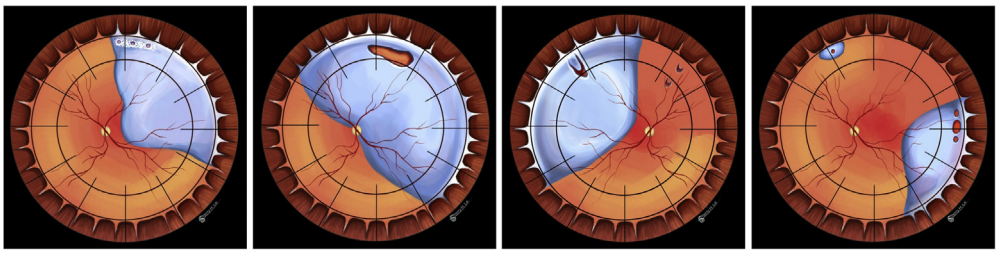
Procedures

Time to the allocated intervention was dependent on macular status: within 24 or 72 hours for macula-attached cases and macula-detached cases, respectively. These timings referred both to the primary intervention and any subsequent operations for recurrent or persistent retinal detachment. Formal trial visits and observations took place at baseline, 1 day, 1 week, and 1, 3, 6, and 12 months after surgery. Any number of additional visits were permissible as required for that patient's care. Clinical examination and measurement of best-corrected Snellen VA took place at every visit (and additionally per Early Treatment Diabetic Retinopathy Study [ETDRS] protocol at 3, 6, and 12 months). Assessment of baseline VA was carried out, but often under less controlled conditions because of clinical urgency (for example, after pharmacologic dilation or due to presentation outside normal working hours). Cataract grading (Lens Opacity Classification System [LOCS] III)[6] was carried out at baseline and months 3, 6, and 12 after surgery. Phakic patients underwent an additional examination at 9 months to ensure that those demonstrating visually significant cataract underwent cataract surgery before the 1-year final vision assessment. An assessment of subjective health-related quality of life (36-item Short Form Health Survey version 2) was made at baseline and repeated at 1 month. Subjective visual function was assessed at 3, 6, and 12 months (25-item National Eye Institute Visual Function Questionnaire).[7] Finally, spectral-domain OCT (Cirrus HD-OCT; Carl Zeiss Meditec, Jena, Germany) was carried out at each visit, and an objective assessment of metamorphopsia took place at 1 year (M-CHARTS, Inami & Co, Ltd, Tokyo, Japan).[8]

Our surgical technique for PnR is hereby summarized. First, patients underwent a thorough scleral-depressed peripheral retinal examination to identify all pathologic features at every visit. Second, laser retinopexy was applied to all breaks, lattice degeneration, or both in the attached retina before gas injection. Third, breaks in the detached retina were treated with cryotherapy before gas injection or (preferably) laser retinopexy 24 to 48 hours after gas injection, with additional laser retinopexy applied at any point per surgeon discretion. Finally, anterior chamber paracentesis was used to express as much fluid as safely possible (generally $\geq$0.3 ml), followed by injection of 100% sulphur hexafluoride (SF_6; ideally $\geq$0.6 ml). Most patients underwent a so-called steam-roller maneuver to expedite retinal reattachment (by pushing some subretinal fluid [SRF] through the retinal break) and to protect the macula from displaced SRF. The authors favor SF_6 gas for PnR because it reaches maximum size rapidly and has a shorter duration until dissipation. In those specific patients in whom a larger gas bubble (SF6) or a longer duration of tamponade is required, the authors prefer adding a second gas bubble at the appropriate time point. This was often preplanned, for example, in a patient with a superotemporal break in the detached retina and an inferotemporal break in the attached retina. In such a case, the authors might attempt to steam-roll the patient in such a way as to avoid the SRF from being displaced inferotemporally. Despite this, it is possible that on day 1 or 2 after surgery, the superotemporal break is secure with retinopexy in situ, but the inferotemporal break may have become lifted by the displaced fluid. In such a situation, the authors might reinject a second bubble of SF_6 to achieve a larger area of retinal contact and position the patient flat on the side, so as to tamponade both the superotemporal and inferotemporal retinal breaks. Thus, subsequent supplementary gas injection or laser application were permissible at the surgeon's discretion. Additional details on the PnR technique are provided in the Supplemental Appendix (available at www.aaojournal.org).

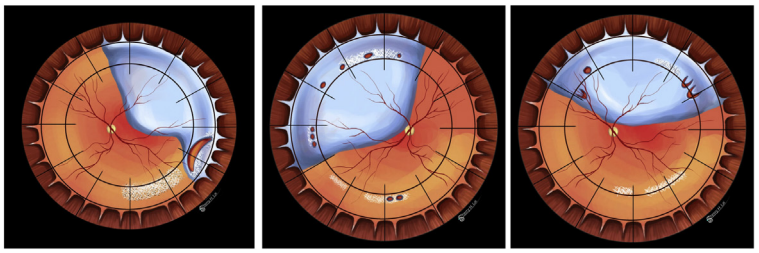
Pars plana vitrectomy procedures were performed by experienced vitreoretinal surgeons (A.R.B., D.T.W., F.A., L.R.G., R.H.M., R.J.H.) performing high volumes of surgery, and all technical nuances of the surgery were carried out at their discretion and per standard of care in North America and Europe. The following is a general description of the PPV technique used. Surgery took place using a 23-gauge system, with 360° peripheral vitreous shave visualized by scleral indentation. Laser retinopexy was preferred to treat most retinal pathologic features, including lattice degeneration, breaks in the attached retina, and the break(s) responsible for the retinal detachment. However,

Inclusion*	(i)	A single retinal break or group of breaks, no larger than one clock hour (30°), in detached retina
	(ii)	All breaks in detached retina to lie above the 8 and 4 o'clock meridian
	(iii)	Breaks or lattice degeneration in attached retina at any location (even inferior) were allowed



*Illustrations of example cases meeting the inclusion criteria.

Exclusion**	(i)	Inferior breaks in detached retina
	(ii)	Significant media opacity (e.g. vitreous haemorrhage or cataract preventing detailed retinal examination)
	(iii)	Proliferative vitreoretinopathy (PVR) grade B or worse
	(iv)	Previous retinal detachment (index eye)
	(v)	Previous PPV (index eye)
	(vi)	Age <18 years
	(vii)	Mental incapacity
	(viii)	Inability to read English language
	(ix)	Pre-existing ocular diagnosis that would impact on visual outcome
	(x)	Physical inability to posture post-operatively



**Illustrations of example cases not meeting the inclusion criteria.

Figure 1. Inclusion and exclusion criteria for the prospective, randomized controlled Pneumatic Retinopexy versus Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial. PPV = pars plana vitrectomy.

supplementary cryopexy was applied sparingly or as needed in patients with small, peripheral, anterior retinal breaks. Subretinal fluid generally was drained through the break responsible for the retinal detachment, after marking it with endodiathermy. However, the use of heavy liquid or posterior retinotomy were at the surgeon's discretion. A complete air–fluid exchange was performed, and isoexpansile SF_6 or perfluoropropane gas was injected. Generally, SF_6 was preferred, with perfluoropropane used in patients with inferior pathologic features or traction evident at the time of surgery. The use of adjunctive surgical techniques, such as placement of a scleral buckle, silicone oil, or combined cataract extraction, were permissible but were used rarely. Patients were placed face down immediately after PPV, except in macula-attached patients with no SRF close to the posterior pole at the end of surgery, in which case they were positioned according to the location of the retinal break. Pneumatic retinopexy procedures were carried out under local (subconjunctival) anesthesia in an office setting, whereas PPV was performed under local (sub-tenon or retrobulbar) anesthesia plus sedation in an operating room.

Where the primary intervention failed, the nature of the second operation was at the discretion of the surgeon, to take place within the time limits specified above. Care was taken to posture the patient face down to protect the macula and the lens from gas-related opacity while awaiting secondary surgery.

Outcomes

The primary outcome was VA (ETDRS letters) at 12 months after intervention. Important secondary outcomes were VA (ETDRS letters) at 3 and 6 months; primary anatomic success (defined as complete retinal attachment with a single procedure, in the absence of a tamponade agent) at 12 months; proportion of patients achieving 70 ETDRS letters or more at 1 year (Snellen equivalent, 20/40); subjective visual function (25-item National Eye Institute Visual Function Questionnaire results) at 3, 6, and 12 months;

health-related quality of life (36-item Short Form Health Survey version 2 results) assessment at 1 month after intervention versus baseline; and vertical and horizontal metamorphopsia scores at 12 months after intervention. Additionally, the proportion of patients requiring cataract surgery and the incidence of other complications were noted.

Statistical Analysis

A sample size calculation was carried out in relation to the primary outcome, using the following assumptions: power, 90%; α, 0.05; standard deviation, 20 ETDRS letters; and a difference in means of 10 ETDRS letters. In fact, the standard deviation for ETDRS VA in the study was smaller than the original estimates, which allowed for the detection of smaller differences in the primary outcome between groups. Allowing for an anticipated 10% dropout rate, this yielded a sample size of 176 (n = 88 per group). Baseline characteristics, procedure characteristics, treatment burden, and primary and secondary outcomes were summarized descriptively using means and standard deviations for continuous variables, as well as frequency and proportions for categorical variables. The primary analysis was an intention-to-treat analysis. Visual acuity (ETDRS letters) at 12 months was compared between groups using a 2-sided α of 0.05. Patients who had missing 1-year data were not included in the primary outcome analysis; we did not carry forward VA results. Secondary analyses included linear regression models for continuous outcomes and logistic regression models for binary outcomes. Baseline macular status was adjusted for in a regression analysis of VA and metamorphopsia scores at 12 months as a sensitivity analysis. Confidence intervals for the primary and secondary outcomes are 2-sided 95% confidence intervals. Separate linear and logistic regression models were constructed to examine whether the effect of treatment group differs between those who have macula-on or macula-off status and those who are phakic or pseudophakic at baseline on ETDRS and primary retinal reattachment rate respectively at 12 months. This was achieved by examining the effect of the interaction term between treatment groups and both macula and lens status separately. Analyses were performed using R statistical package version 3.4.3 (R Core Team; www.r-project.org; Vienna, Austria).

There was no funding source for this study.

Results

One hundred seventy-six patients were recruited between August 2012 and May 2016. Seventy-seven patients (87.5%) in the PnR group and 73 patients (83%) in the PPV group completed the 1-year assessment, with most of the remainder reached or examined at a later date (see trial profile, Fig 2). Both groups generally were similar at baseline. However, the number of breaks in attached retina (and consequently the number of retinal breaks overall) differed between the treatment arms: 0.5 versus 0.2 breaks in attached retina ($P = 0.03$) and 2.0 versus 1.6 breaks overall ($P = 0.01$) for the PnR and PPV groups, respectively (Table 1).

All macula-attached eyes and most macula-detached eyes proceeded to intervention within 24 hours from randomization, but the PnR group received the intervention more swiftly (median, 2.0 hours [interquartile range (IQR), 1.0−4.0 hours] vs. 19.1 hours [IQR, 8.0−25.7 hours] for the PnR and PPV groups, respectively; $P < 0.001$). However, where applicable, the time from macular detachment (determined by self-reported loss of central vision) to intervention was similar (median, 2.0 days [IQR, 0.8−5.0 days] vs. 1.5 days [IQR, 0.8−5.0 days] for the PnR and PPV groups, respectively; $P = 0.9$). Additional procedure characteristics for PnR and PPV are listed in Table 2.

The ETDRS VA after PnR exceeded that after PPV at every time point to 12 months: by 9.9 letters at 3 months (78.4±12.3 letters vs. 68.5±17.8 letters), by 10.6 letters at 6 months (79.2±11.1 letters vs. 68.6±17.2 letters), and by 4.9 letters at 12 months (79.9±10.4 letters vs. 75.0±15.2; $P = 0.024$; Fig 3). The difference in ETDRS VA at 1 year remained statistically significant after adjusting for baseline macular status ($P = 0.03$). The proportion of patients achieving 70 ETDRS letters or more (approximate Snellen equivalent, 20/40) was 90.3% (65/72 patients) in the PnR group versus 75.3% (55/73 patients) in the PPV group ($P < 0.017$). At 12 months, 80.8% of patients (63/78) undergoing PnR versus 93.2% of patients (68/73) undergoing PPV achieved primary anatomic success ($P < 0.045$). Of these, 7 in the PnR arm received additional gas injections between postoperative days 2 and 19. Ultimately, 98.7% and 98.6% in the PnR and PPV groups, respectively, achieved secondary anatomic success. Linear regression models did not show evidence of a difference in the effect of treatment group between those with macula-on versus macula-off status ($P = 0.586$) and those who were phakic versus pseudophakic ($P = 0.452$) on EDTRS VA at 12 months (Table 3). Similarly, logistic regression models did not show evidence of a difference in the effect of treatment group between those with macula-on versus macula-off status ($P = 0.647$) and those who were phakic versus pseudophakic ($P = 0.300$) on the primary retinal reattachment rate at 12 months.

Composite 25-item National Eye Institute Visual Function Questionnaire scores were superior in the PnR group at 3 and 6 months, with similar scores at 1 year (Fig 4). A linear regression model demonstrated no statistically significant difference in the 36-item Short Form Health Survey health-related quality-of-life scores (physical and mental components, $P = 0.484$ and $P = 0.096$, respectively) between the 2 arms at 1 month while controlling for baseline values. Vertical metamorphopsia scores were superior in the PnR group compared with the PPV group at 12 months (0.14±0.29 vs. 0.28±0.42; $P = 0.026$). This difference remained statistically significant after controlling for macular status ($P = 0.03$). The difference in horizontal metamorphopsia scores did not reach statistical significance (0.15±0.33 in the PnR group vs. 0.24±0.46 in the PPV group; $P = 0.25$). Considered categorically, 41.7% of patients (25/60) versus 34.8% of patients (23/66) demonstrated objective horizontal metamorphopsia after PPV and PnR, respectively ($P = 0.43$), and 56.7% of patients (34/60) versus 37.9% of patients (25/66) demonstrated objective vertical metamorphopsia after PPV and PnR, respectively ($P = 0.035$). On assessment of macrostructural abnormalities on spectral-domain OCT, there were similar rates of epiretinal membrane (ERM) and intraretinal cystic changes between the groups.

Patients undergoing PnR attended a mean of 10.8±2.7 office visits compared with 9.6±2.1 in the PPV group ($P < 0.001$). This difference in number of office visits is attributed to the need for laser retinopexy in the first few days after PnR. With regard to morbidity, 81% of phakic patients in the PPV arm demonstrated cataract progression (defined as progression of 2.0 units or more within any individual LOCS III subgrade), underwent cataract extraction by 12 months, or both versus 29% for the PnR arm ($P < 0.001$), and 65% of phakic patients in the PPV arm underwent cataract surgery in the study eye before 12 months versus 16% for the PnR arm ($P < 0.001$). Mean LOCS III scores at 1 year for nuclear color, nuclear opalescence, posterior subcapsular, and cortical subgrades were 0.66, 0.67, 0.22, and 0.19, respectively, for the PPV arm and 1.1, 1.1, 0.34, and 0.13, respectively, for the PnR arm, with pseudophakic patients assigned values of 0. Besides cataract, 7 patients in the PnR group and 11 patients in the PPV group required topical treatment for cystoid macular edema. Two

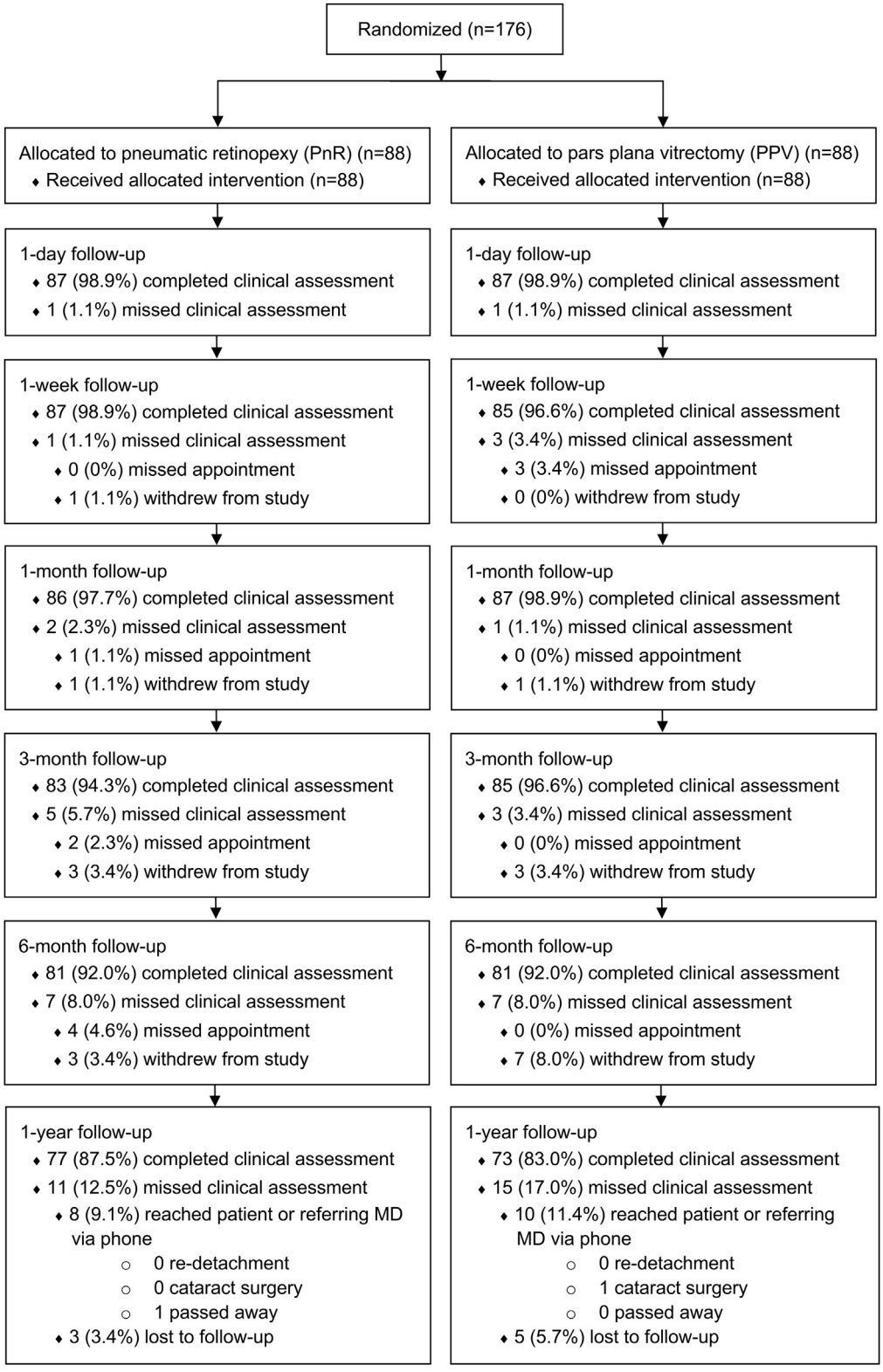


Figure 2. Flowchart showing the randomization and follow-up of the intention-to-treat population.

patients in each group required additional PPV for visually significant ERM, and 1 patient in the PPV group required additional PPV for macular hole. No patients required PPV for vitreous debris. One patient in the PnR arm developed bacterial endophthalmitis that responded well to treatment; the patient achieved VA of 20/50.

Table 1. Baseline Patient and Study Eye Characteristics

Variable	Pneumatic Retinopexy (n = 88)	Pars Plana Vitrectomy (n = 88)	P Value
Age (yrs), mean (SD)	60.7 (10.1)	60.3 (7.8)	0.77
Male gender, no. (%)	61 (69)	55 (62)	0.34
Right study eye, no. (%)	54 (61)	39 (44)	0.02*
Pre-operative ETDRS visual acuity, mean (SD)	46 (37)	43 (37)	0.68
Macular status			
On	77 (14)	75 (19)	
Off	14 (23)	11 (21)	
Lens status			
Pseudophakic	47 (37)	43 (38)	
Phakic	45 (37)	44 (37)	
Preoperative lens status, no. (%)			0.42
Pseudophakic	31 (35)	26 (30)	
Phakic	57 (65)	62 (70)	
Lens grading for phakic patients			
Nuclear color, mean (SD)	1.85 (0.75)	1.71 (0.86)	0.36
Nuclear opalescence, mean (SD)	1.81 (0.77)	1.65 (0.77)	0.27
Cortical, mean (SD)	0.47 (0.51)	0.60 (0.81)	0.31
Posterior subcapsular, mean (SD)	0.28 (0.44)	0.24 (0.38)	0.65
Macular status, no. (%)			0.32
Macula-on retinal detachment	44 (50)	44 (50)	
Macula-off retinal detachment	44 (50)	44 (50)	
Characteristics of retinal detachment			
No. of breaks in attached retina, no. (%)			
None	63 (72)	74 (84)	
1–2	20 (23)	13 (15)	
3–4	4 (5)	1 (1)	
>4	1 (1)	0	
Mean (SD)	0.5 (1.0)	0.2 (0.56)	0.03*
Total no. of breaks in attached and detached retina, no. (%)			
1–2	71 (81)	77 (88)	
3–4	10 (11)	11 (12)	
>4	7 (8)	0	
Mean (SD)	2.0 (1.4)	1.6 (0.86)	0.01*
Location of the lowest break category, no. (%)†			0.50
Category 1: 12-o'clock meridian	13 (15)	10 (11)	
Category 2: 11- or 1-o'clock meridians	32 (36)	34 (39)	
Category 3: 10- or 2-o'clock meridians	27 (31)	32 (36)	
Category 4: 9- or 3-o'clock meridians	12 (14)	12 (14)	
Category 5: 8- or 4-o'clock meridians	4 (5)	0	
No. of quadrants of retinal detachment, mean (SD)	1.81 (0.79)	1.65 (0.73)	0.15

ETDRS = Early Treatment Diabetic Retinopathy Study; SD = standard deviation.
*$P < 0.05$.
†Classification is based on a priori knowledge of likelihood of success for reattachment with pneumatic retinopexy based on location of the lowest break.

Discussion

The key finding of this trial is that patients undergoing PnR for primary RRD achieved superior ETDRS VA compared with those undergoing PPV at every time point up to and including the primary end point at 12 months after intervention. It is possible that the VA in both groups might have improved further, given more time and additional cataract surgery. There was also an advantage for PnR in self-reported vision-related quality of life at 3 and 6 months. There was no significant difference in the effect of treatment group with respect to macula or lens status at presentation.

Patients who underwent PnR also demonstrated less objectively measured vertical metamorphopsia at 12 months. We identified no difference in macroscopic OCT changes such as ERM between groups. We suspect that the superior visual function with PnR is likely multifactorial, related to a less invasive and expedited procedure with reduced morbidity and a more natural reattachment of the retina. To minimize disparity in time to surgery between the groups, every effort was made to carry out all trial interventions within a short time frame. In the macula-on and macula-off groups, the mean times to PPV were 7.5 and 18.1 hours, respectively. These timings fall well within generally accepted best practice, and thus we expect that the visual results achieved in the PPV arm in this trial setting likely exceed that achieved in day-to-day practice.

The anatomic inclusion criteria used in this trial were relatively broad, with inferior breaks in attached retina being acceptable. Posterior hyaloid status (attachment or detachment) was not included in these criteria because in our routine clinical practice, this factor does not influence the decision to

Table 2. Operative Details for Pneumatic Retinopexy and Pars Plana Vitrectomy

Variable	Value
Pneumatic retinopexy	
Intraocular sulphur hexafluoride volume (ml), mean (SD) / range	0.645 (0.11) / 0.45–1.15
Anterior chamber paracentesis volume (ml), mean (SD) / range	0.350 (0.11) / 0.20–0.75
Patients requiring laser treatment, no. (%)	
Before pneumatic retinopexy	42 (48)
Within 2 wks after pneumatic retinopexy	78 (89)
Total no. of laser treatment shots before and after surgery, mean (SD)	990.8 (642.1)
Patients requiring cryotherapy, no. (%)	21 (24)
Patients requiring additional gas injection, no. (%)*	7 (8)
Pars plana vitrectomy	
Laser treatment	
Patients receiving laser treatment, no. (%)	65 (74)
Laser shots received, mean (SD)	491.0 (406.8)
Cryotherapy, no. (%)	42 (48)
Gas tamponade type, no. (%)	
Sulphur hexafluoride	55 (62)
Perfluoropropane	33 (38)
Additional interventions, no. (%)	
Combined cataract extraction	1 (1)
Scleral buckle	1 (1)
Intravitreal dexamethasone injection (400 μg/0.1 ml)	27 (31)

SD = standard deviation.
*Number of patients requiring additional gas injections within 3 weeks after the operative procedure. Any additional gas injection beyond 3 weeks was considered a failure of primary treatment.

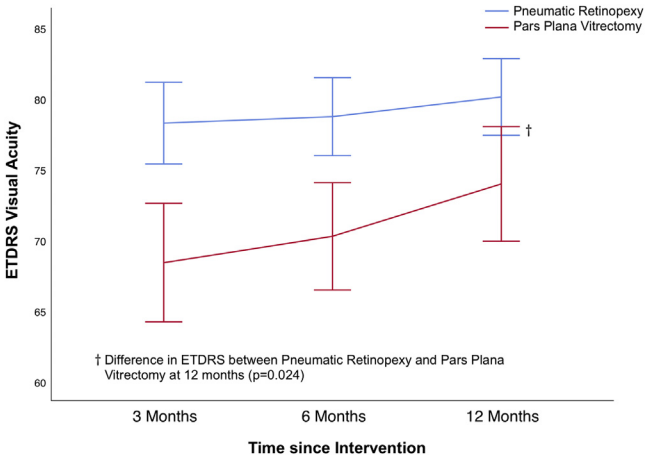


Figure 3. Graph showing the primary outcome, Early Treatment Diabetic Retinopathy Study (ETDRS) visual acuity, for the pneumatic retinopexy and pars plans vitrectomy intention-to-treat groups at 3, 6, and 12 months of follow-up. Error bars represent 95% confidence intervals.

proceed with PnR. Despite this, patients undergoing PnR achieved a primary retinal reattachment rate of 81% compared with 93% of patients undergoing PPV. It is important to note that the small group of patients who incurred a failed primary intervention in the PnR group went on to achieve good final VA (mean, 70.8 ETDRS letters; Snellen equivalent, >20/40). Where a secondary operation was indicated to manage a failed primary PnR, no technical difficulties were incurred. Pneumatic retinopexy also was associated with a markedly lower incidence of cataract compared with the PPV group. Very few patients in either group required additional surgery for visually significant ERM, macular hole, or vitreous debris. Patients undergoing PnR avoid the potential risks of periocular anaesthetic injection and sedation or general anesthesia. We found that the rate of retinal redetachment after 3 months was very low in both groups (1 in the PnR group and 2 in the PPV group), thus confirming PnR as a definitive and durable treatment. One perceived drawback for PnR is the need for extra visits. This study showed that there was one additional visit on average for patients undergoing PnR.

Increased use of PnR would achieve significant cost savings while providing superior visual outcomes.[9] Unlike PPV, with PnR there are few material barriers to administering care, such as the requirement for specialist equipment (e.g., vitrectomy system) or an operating room environment. This has obvious implications for facilitating the timely management of RRD in remote areas or developing countries, where operating resources may be scarce. Developing PnR expertise by qualified ophthalmologists in these areas could allow for 4 of every 5 patients with acute RRD who meet Pneumatic Retinopexy versus Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial inclusion criteria to receive successful treatment that they may not have obtained otherwise, with visual results superior to those of patients undergoing primary PPV.

This trial has certain limitations. First, 12.5% of patients (11/88) versus 17.0% of patients (15/88) in the PnR and PPV groups, respectively, did not complete the 1-year ETDRS VA assessment. This represents the large geographical area served that presented a barrier to follow-up. There was no difference in the baseline retinal detachment characteristics (including macular status and duration of macular detachment), VA, or lens status between those who did and did not attend a 1-year assessment. Those who failed to attend the 1-year visit were followed up at a later time point or contacted by phone to confirm that they were doing well, and they generally requested less rigorous follow-up closer to home. In total, 8 patients (3 in the PnR group and 5 in the PPV group) could not be reached to confirm that they had not required additional retinal procedures in the study eye. There was a disparity in the number of retinal breaks at baseline (in attached retina and overall), with more apparent breaks in the PnR arm, which may have biased anatomic success in favor of the PPV arm. Long-acting gas tamponade (perfluoropropane) was used in a proportion of patients (38%) in the PPV arm only. Although this disparity is of doubtful importance, it conceivably could have influenced anatomic success in favor of PPV and enhanced cataract formation in the PPV arm. It is likely that not every phakic patient with clinically significant cataract underwent cataract extraction surgery before 12 months in both groups. Although trial observations prompted swift identification and an offer of cataract surgery, some patients opted to decline. Therefore, it is possible that untreated lens opacities in a small minority of

Table 3. Breakdown of Visual Outcomes

Variable	Pneumatic Retinopexy (n = 88)	Pars Plana Vitrectomy (n = 88)
Postoperative ETDRS visual acuity at 1 yr, mean (SD)		
Macular status		
Macula-on retinal detachment	84 (8)	78 (14)
Macula-off retinal detachment	76 (11)	72 (16)
Lens status		
Pseudophakic	80 (12)	77 (21)
Phakic	80 (9)	74 (13)

ETDRS = Early Treatment Diabetic Retinopathy Study; SD = standard deviation.

patients might have impacted the visual outcome. This is a reality encountered in everyday practice, whereby patients may opt not to undergo swift removal of the cataract. The study investigators believe that the timely cataract surgery for most phakic patients in the PPV group likely biased 1-year VA results in favor of PPV. This is supported by the overall higher LOCS III scores in the PnR group at 1 year.

In the PnR group, 18.8% less patients demonstrated vertical distortion. Clinicians in everyday practice frequently encounter patients who have achieved apparently successful retinal detachment repair with excellent VA, but intolerable distortion. Superior objective vertical distortion measurements are a significant advantage for patients undergoing PnR as a primary procedure.

It is important to note that the primary anatomic success rate was significantly higher with PPV versus PnR (93.2% vs. 80.8%), as expected a priori. However, it is also important to put these differences in context. With anatomic success rates favoring PPV by 12%, the number needed to treat to avoid 1 secondary PPV is 8.33. The 93% success rate in the PPV group is the highest reported success rate from a randomized trial involving a vitrectomy arm. A PPV first approach effectively would advocate treating more than 8 patients to avoid 1 from requiring a secondary procedure, while exposing the remaining 7 to potentially avoidable outcomes such inferior VA, worse vertical metamorphopsia, and cataract surgery to one or both eyes (to avoid anisometropia).

For PnR to gain widespread popularity as a first-line technique would require a global paradigm shift in terms of surgical training and practice.[10,11] Clinicians considering adding PnR to their armamentarium for RRD repair require training and experience. There is an art to PnR, much like for SB or PPV surgery. Nuances such as patient selection, identification and treatment of breaks, and maximizing anterior chamber tap volume and bubble size are crucial to optimize success and minimize complications. Primary PnR should be considered the first-line treatment for RRD in

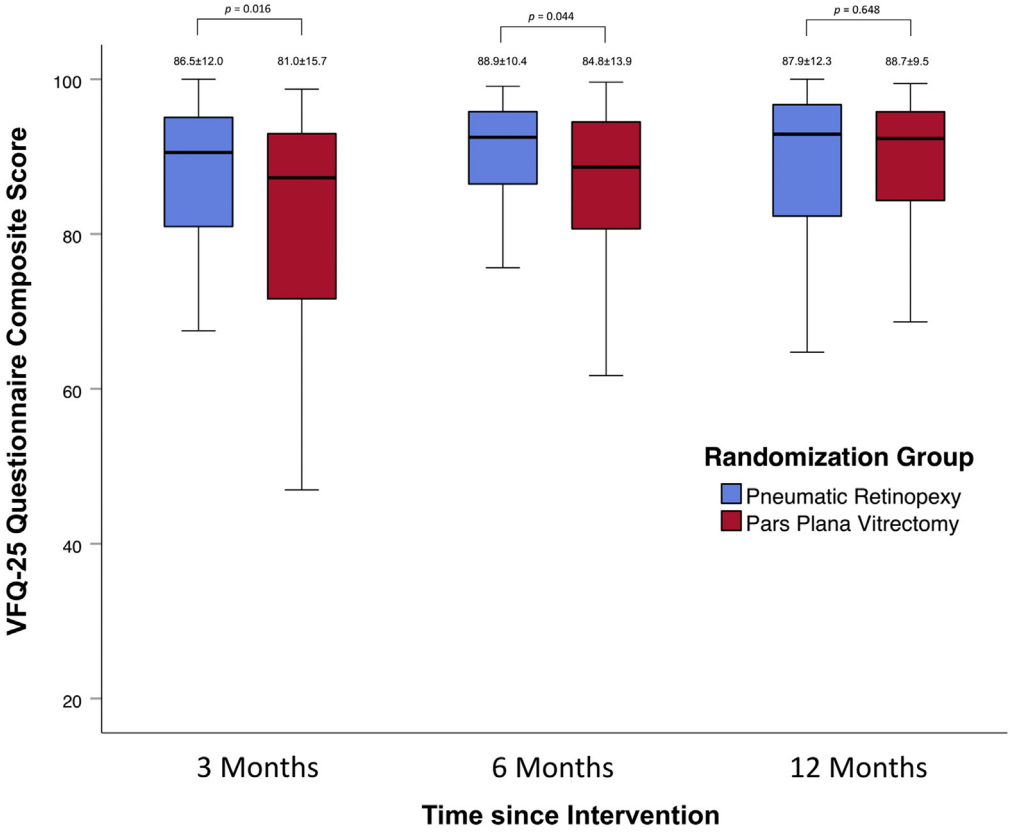


Figure 4. Box-and-whisker plot showing composite 25-item National Eye Institute Visual Function Questionnaire (NEI VFQ-25) scores for the pneumatic retinopexy and pars plana vitrectomy intention-to-treat groups at 3, 6, and 12 months of follow-up. Error bars represent standard deviation. Plus-minus values represent mean plus-minus standard deviation.

patients fulfilling Pneumatic Retinopexy versus Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial (PIVOT) recruitment criteria. This trial demonstrated that primary PnR offers superior 1-year VA, less vertical metamorphopsia, and reduced morbidity when compared with primary PPV.

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Abbreviations and Acronyms:
ERM = epiretinal membrane; **ETDRS** = Early Treatment Diabetic Retinopathy Study; **IQR** = interquartile range; **LOCS** = Lens Opacity Classification System; **PnR** = pneumatic retinopexy; **PPV** = pars plana vitrectomy; **RRD** = rhegmatogenous retinal detachment; **SB** = scleral buckling; **SF_6** = sulphur hexafluoride; **SRF** = subretinal fluid; **VA** = visual acuity.

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