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Retinal Displacement Following Pneumatic Retinopexy vs Pars Plana Vitrectomy for Rhegmatogenous Retinal Detachment

Koby Brosh, MD; Carolina L. M. Francisconi, MD; Jenny Qian, MD; Francesco Sabatino, MD; Verena R. Juncal, MD; Roxane J. Hillier, MBChB; Varun Chaudhary, MD; Alan R. Berger, MD; Louis R. Giavedoni, MD; David T. Wong, MD; Filiberto Altomare, MD; Mustafa R. Kadhim, MBBS; Richard B. Newsom, MBBS; Samara B. Marafon, MD; Rajeev H. Muni, MD, MSc

IMPORTANCE Retinal displacement following rhegmatogenous retinal detachment repair may have consequences for visual function. It is important to know whether surgical technique is associated with risk of displacement.

OBJECTIVE To compare retinal displacement following rhegmatogenous retinal detachment repair with pneumatic retinopexy (PR) vs pars plana vitrectomy (PPV).

INTERVENTIONS OR EXPOSURES Fundus autofluorescence images were assessed by graders masked to surgical technique.

DESIGN, SETTING, AND PARTICIPANTS A multicenter retrospective consecutive case series in Canada and the UK. A total of 238 patients (238 eyes) with rhegmatogenous retinal detachments treated with PR or PPV who underwent fundus autofluorescence imaging from November 11, 2017, to March 22, 2019, were included.

MAIN OUTCOMES AND MEASURES Proportion of patients with retinal displacement detected by retinal vessel printings on fundus autofluorescence imaging in PR vs PPV.

RESULTS Of the 238 patients included in the study, 144 were men (60.5%) and 94 were women (39.5%); mean (SD) age was 62.0 (11.0) years. Of the 238 eyes included in this study, 114 underwent PR (47.9%) and 124 underwent PPV (52.1%) as the final procedure to achieve reattachment. Median time from surgical procedure to fundus autofluorescence imaging was 3 months (interquartile range, 1-5 months). Baseline characteristics in both groups were similar. The proportion of eyes with retinal vessel printing on fundus autofluorescence was 7.0% for PR (8 of 114) and 44.4% for PPV (55 of 124) (37.4% difference; 95% CI, 27.4%-47.3%; $P < .001$). Analysis based on the initial procedure found that 42.4% (42 of 99) of the eyes in the PPV group vs 15.1% (21 of 139) of the eyes in the PR group (including 13 PR failures with subsequent PPV) had displacement (27.3% difference; 95% CI, 15.9%-38.7%; $P < .001$). Among eyes with displacement in the macula, the mean (SD) displacement was 0.137 (0.086) mm (n = 6) for PR vs 0.297 (0.283) mm (n = 52) for PPV (0.160-mm difference; 95% CI, 0.057-0.263 mm; $P = .006$). Mean postoperative logMAR visual acuity was 0.31 (0.32) (n = 134) (Snellen equivalent 20/40) in eyes that initially underwent PR and 0.56 (0.42) (n = 84) (Snellen equivalent 20/72) in eyes that had PPV (−0.25 difference; 95% CI, −0.14 to −0.35; $P < .001$). Among eyes with displacement, mean postoperative logMAR visual acuity was 0.42 (0.42) (n = 20) (Snellen equivalent 20/52) in those that initially underwent PR and 0.66 (0.47) (n = 33) (Snellen equivalent 20/91) in those that initially underwent PPV (−0.24 difference; 95% CI, −0.48 to 0.01; $P = .07$).

CONCLUSIONS AND RELEVANCE These findings suggest that retinal displacement occurs more frequently and is more severe with PPV vs PR when considering the initial and final procedure used to achieve retinal reattachment. Recognizing the importance of anatomic integrity by assessing retinal displacement following reattachment may lead to refinements in vitreoretinal surgery techniques.

Video

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Rajeev H. Muni, MD, MSc, Unity Health Toronto, Department of Ophthalmology, St Michael's Hospital, 30 Bond St, 8 Cardinal Carter Wing South, 8-043, Toronto, ON M5B 1W8, Canada (rajeev.muni@gmail.com).

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Pneumatic retinopexy (PR) is a technique that relies on reabsorption of subretinal fluid by the retinal pigment epithelium after occlusion of the retinal break by an intravitreal gas bubble. Although pars plana vitrectomy (PPV) with internal drainage, air-fluid exchange, and near complete gas tamponade has become increasingly popular, there is still debate about the optimal technique to repair most rhegmatogenous retinal detachments.

The Pneumatic Retinopexy vs Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial (PIVOT) randomized patients to PPV vs PR for patients with retinal breaks within 1 clock hour in the detached retina, with any number, location, and size of retinal breaks or lattice degeneration in the attached retina.[1] The study found that patients who underwent PR had superior functional outcomes with superior Early Treatment Diabetic Retinopathy Study visual acuity at every time point, including the 1-year end point. Of particular interest was that patients in the PPV group had significantly more objectively measured vertical distortion compared with patients undergoing PR. We hypothesized that this difference in metamorphopsia may be associated with differences in the realignment of the photoreceptors to the retinal pigment epithelium after repair.

In 2010, Shiragami et al[2] reported the presence of hyperautofluorescent lines on fundus autofluorescence imaging in 62.8% of patients undergoing PPV for rhegmatogenous retinal detachment. These lines were termed *retinal vessel printings* by Dell'Omo et al[3] and *retinal pigment epithelium vessel ghosts* by Lee et al.[4] Shiragami et al[2] hypothesized that the hyperautofluorescent lines were associated with changes in metabolic activity in the retinal pigment epithelium cells once exposed to light after displacement, whereas Dell'Omo et al[3] suggested that the presence of the printings was associated with variable composition and characteristics of retinal pigment epithelium fluorophores in cells that were previously concealed.

The primary objective of this study was to investigate whether there is a difference in the macrostructural integrity of retinal reattachment between PR and PPV by determining the proportion of patients with postoperative retinal displacement detected by retinal vessel printing on fundus autofluorescence imaging. A secondary objective was to determine whether retinal displacement is associated with postoperative metamorphopsia and microstructural integrity of the outer retina on optical coherence tomographic scans.

Key Points

Question Is there a difference in retinal displacement following rhegmatogenous retinal detachment repair with pneumatic retinopexy vs pars plana vitrectomy?

Findings This case series including 238 eyes found that retinal displacement detected by retinal vessel printings on fundus autofluorescence imaging developed in 7.0% of pneumatic retinopexy–treated eyes vs 44.4% of pars plana vitrectomy–treated eyes.

Meaning These results suggest that retinal displacement may be more severe and occurs more frequently with pars plana vitrectomy vs pneumatic retinopexy.

Methods

The study was approved by the research ethics board at St Michael's Hospital/Unity Health Toronto in Toronto, Ontario, Canada, and the Hamilton Regional Eye Institute in Hamilton, Ontario, Canada. As this study was a retrospective analysis of patients who underwent fundus autofluorescence imaging and prior retinal detachment repair and were not part of a prospective trial, the study did not require patient informed consent as determined by the general policies of the research ethics board because many patients who had imaging in the past may no longer be following up with that specific site and it was thought to be impractical to obtain patient informed consent. There had been no compensation or incentive for patients. At the third site, Newcastle Eye Centre in Newcastle upon Tyne, UK, this study was considered a service evaluation according to National Health Service Health Research Authority guidance; thus, formal research ethics committee review was not required. The study adhered to the tenets of the Declaration of Helsinki.[5]

Study Population

This multicenter, retrospective, case series study was carried out at 3 academic vitreoretinal units that included patients who had fundus autofluorescence imaging from November 11, 2017, to March 22, 2019, following rhegmatogenous retinal detachment repair with PR or PPV for acute rhegmatogenous retinal detachment with no substantial proliferative vitreoretinopathy (PVR) (grade B or less). The primary outcome was the proportion of patients with retinal displacement detected by retinal vessel printings shown on fundus autofluorescence imaging in PPV vs PR as the final procedure to achieve retinal reattachment.

Three institutions with broadly different preferred surgical strategies for rhegmatogenous retinal detachment repair were chosen in an attempt to have balanced baseline characteristics. St Michael's Hospital/Unity Health Toronto performs a large number of PRs as primary treatment for many rhegmatogenous retinal detachments. The other 2 sites infrequently use PR. Hamilton Regional Eye Institute performs predominantly primary PPV, often using posterior retinotomy for drainage. Newcastle Eye Centre performs predominantly primary PPV for most rhegmatogenous retinal detachment, often draining through the responsible retinal break. Visual acuity at the time of fundus autofluorescence imaging was recorded at all sites. At one institution (St Michael's Hospital/Unity Health Toronto), patients also had objective measurements of metamorphopsia (M-CHARTS, Inami & Co Ltd) and aniseikonia (Awaya New Aniseikonia Tests, Handaya Co Ltd). Fundus autofluorescence and optical coherence tomographic images were reviewed and graded as detailed in the following subsection.

Procedures

Pneumatic retinopexy was performed by 6 experienced surgeons (R.J.H., A.R.B., L.R.G., D.T.W., F.A., and R.H.M.) as described in the PIVOT study.[1] In most patients who received PR, the steam-rolling maneuver was performed to reattach the macula and express fluid through the retinal break before positioning the patient to place the apex of the bubble at the location of the break. Pars plana vitrectomy was performed by 9 experienced vitreoretinal surgeons (R.J.H., V.C., A.R.B., L.R.G., D.T.W., F.A., M.R.K., R.B.N., and R.H.M.). Patients had complete 23-gauge PPV with shaving of the vitreous base. Air-fluid exchange was performed by drainage through the responsible retinal break or a posterior retinotomy. While draining through the peripheral break was conducted, care was taken to minimize posterior displacement of residual fluid to the greatest extent possible. Perfluorocarbon liquid was used at the discretion of the surgeon. Laser retinopexy or cryopexy was used to treat the retinal breaks. Isoexpansile sulfur hexafluoride, perfluoroethane, or perfluoropropane was used with immediate initial face down positioning in all but 4 cases.

Anonymized widefield fundus autofluorescence images (Optos California, Optos Inc) from all 3 sites were assessed for retinal vessel printing by 2 graders (K.B. and C.L.M.F.) masked to surgical technique. Discordances were resolved by consensus. If there was retinal vessel printing, the amount of displacement was measured in millimeters, using the Optos calipers under high magnification. If the displacement was present but less than 0.1 mm, such that it could not be accurately measured, then a value of 0.05 mm was imputed (required for only 2 eyes with PPV and 1 eye with PR). Retinal vessel printing was also assessed in terms of location: zone 1 was defined as a circle that had the fovea as its center and the fovea-disc distance as its radius, and zone 2 was defined as any area outside zone 1. Displacement in zone 1 was measured at several points along the displaced vessel to its corresponding point on the retinal vessel printing, and the largest of these measurements was recorded. An average of the largest measurements from the 2 masked graders was used for statistical analysis. The direction of displacement was also evaluated.

Cross-sectional high-definition 5-line raster images were obtained (Cirrus HD-OCT; Carl Zeiss Meditec) and were analyzed by 2 masked investigators (C.L.M.F. and V.R.J.). Graders assessed optical coherence tomographic images for epiretinal membrane and cystoid macular edema, and microstructural changes, including disruption of the external limiting membrane, ellipsoid zone, and the interdigitation zone, as well as outer retinal folds. Discordances were resolved by consensus.

Statistical Analysis

For the primary outcome, the difference in proportion of eyes with retinal displacement between PR and PPV, eyes were included in their respective treatment group if that was the final procedure to reattach the retina. Additional sensitivity analyses on the primary outcome were performed.

Continuous variables are presented as mean (SD). Categorical variables are presented as absolute values and percentages. Visual acuity with pinhole measurements was converted to logMAR scale. The χ^2 test was used to assess associations for categorical outcomes, and 2-sided independent samples *t* test was used to assess associations for continuous outcomes. Results were considered statistically significant if *P* values were <.05. Interobserver agreement for retinal vessel printing measurements was assessed using the interclass correlation coefficient. Statistical analysis was performed using SPSS, version 24 (SPSS Inc).

Results

Of the 238 patients included in the study, 144 were men (60.5%) and 94 were women (39.5%); mean (SD) age was 62.0 (11.0) years. All 238 eyes had sufficient quality fundus autofluorescence images performed at a median of 3 months (interquartile range, 1-5). Of these, 124 eyes (52.1%) had undergone PPV and 114 eyes (47.9%) PR as the final procedure to achieve retinal reattachment. There were similar baseline characteristics, including mean (SD) age (PR success, 61.4 [10.7]; PR failure, 62.2 [10.0]; and primary PPV, 62.7 [11.3] years), lens status (phakic: PR success, 76 [66.7%]; PR failure, 11 [44.0%]; and primary PPV, 54 [54.5%]), macular status (macula-on: PR success, 36 [31.6%]; PR failure, 9 [36.0%]; and primary PPV, 26 [26.3%]), and quadrants of detachment between groups (>2 quadrants: PR success, 38 [33.9%]; PR failure, 12 [52.2%]; and primary PPV, 41 [43.6%]) (**Table 1**). Therefore, no adjustment for baseline characteristics was performed. Among 121 eyes that had PPV and a subretinal fluid drainage method noted, 74 eyes (61.2%) were drained through a peripheral break (perfluorocarbon liquid used in 8 eyes) and 47 eyes (38.8%) through a posterior retinotomy. Of the 121 eyes that underwent PPV and had type of tamponade noted, 23 eyes (19.0%) had sulfur hexafluoride, 22 eyes (18.2%) had perfluoroethane, 72 eyes (59.5%) had perfluoropropane, and 4 eyes (3.3%) had silicone oil.

The proportion of eyes with retinal vessel printing on fundus autofluorescence imaging was 7.0% for PR (8 of 114) and 44.4% for PPV (55 of 124) (37.4% difference; 95% CI, 27.4%-47.3%; *P* < .001). **Figure 1** shows representative examples of patients following PPV and PR for macula-off rhegmatogenous retinal detachment. The proportion with retinal displacement by macular status and displacement characteristics between PR and PPV are presented in **Table 2** and illustrated in **Figure 2**. Among eyes with retinal displacement in zone 1, the mean (SD) displacement was 0.137 (0.086) mm (n = 6) in the PR group vs 0.297 (0.283) mm (n = 52) in the PPV group (0.160-mm difference; 95% CI, 0.057-0.263 mm; *P* = .006). Interobserver agreement for displacement measurements between the masked graders was excellent (interclass correlation coefficient, 0.98; 95% CI, 0.96-0.99).

Among small detachments (1-2 quadrants), retinal displacement occurred in 3 of 74 eyes (4.1%) in the PR group vs 22 of 64 eyes (34.4%) in the PPV group (30.3% difference; 95% CI, 17.8%-42.8%; *P* < .001). Among large detachments (3-4 quadrants), displacement occurred in 5 of 38 eyes (13.2%) that underwent PR vs 29 of 53 eyes (54.7%) that underwent PPV (41.5% difference; 95% CI, 24.4%-58.7%; *P* < .001).

Table 1. Baseline Characteristics of 238 Patients

Characteristic	No. (%)[a]		
	Pneumatic retinopexy		Primary pars plana vitrectomy
	Success	Failure	
Age			
No.	114	25	99
Mean (SD), y	61.4 (10.7)	62.2 (10.0)	62.7 (11.3)
Sex			
No.	114	25	99
Men	65 (57.0)	17 (68.0)	62 (62.6)
Women	49 (43.0)	8 (32.0)	37 (37.4)
Study eye			
No.	114	25	99
Right	65 (57.0)	15 (60.0)	51 (51.5)
Left	49 (43.0)	10 (40.0)	48 (48.5)
Lens status			
No.	114	25	99
Pseudophakic	38 (33.3)	14 (56.0)	44 (44.4)
Phakic	76 (66.7)	11 (44.0)	54 (54.5)
Aphakic	0	0	1 (1.1)
Macular status			
No.	114	25	99
Macula			
On	36 (31.6)	9 (36.0)	26 (26.3)
Off	78 (68.4)	16 (64.0)	73 (73.7)
Detachment size, quadrants			
No.	112	23	94
>2	38 (33.9)	12 (52.2)	41 (43.6)
≤2	74 (66.1)	11 (47.8)	53 (56.4)

[a] The numbers for some variables differ because of missing information.

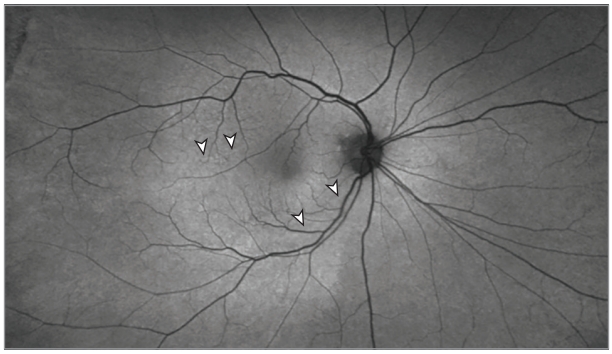
Because a proportion of PR procedures will fail and PPV will be performed, additional subgroup and sensitivity analyses were done including only primary PPVs in the PPV group. Displacement among eyes that had primary PPV (42 of 99 [42.4%]) vs PPV following failed PR (13 of 25 [52.0%]) was similar between groups (9.6% difference; 95% CI, −12.3% to 31.4%; $P = .39$). An analysis based on initial procedure compared eyes that underwent primary PPV vs primary PR. Ninety-nine eyes underwent primary PPV and 139 eyes underwent primary PR. In this analysis, 42 of 99 eyes (42.4%) in the primary PPV group vs 21 of 139 eyes (15.1%) in the primary PR group had displacement (8 eyes with PR success and 13 eyes with PR failure and subsequent PPV) (27.3% difference; 95% CI, 15.9%-38.7%; $P < .001$). Retinal displacement was also compared between primary PR vs primary PPV for eyes that met PIVOT criteria (similar morphologic characteristics). Among 126 eyes that met PIVOT criteria, 12 of 93 eyes (12.9%) in the primary PR (analysis based on initial procedure) group vs 11 of 33 eyes (33.3%) in the primary PPV group had retinal displacement (20.4% difference; 95% CI, 3.0%-37.9%; $P = .009$).

A total of 147 patients (61.8%), all from St Michael's Hospital/Unity Health Toronto, had objective measurements of metamorphopsia, of which 104 patients (70.7%) had PR and 43 patients (29.3%) had PPV. Twenty-five of 30 patients (83.3%) with displacement had some degree of vertical metamorphopsia (score ≥0.1) vs 65 of 117 patients (55.6%) without displacement (27.7% difference; 95% CI, 11.7%-43.9%; $P = .005$). Twenty of 30 patients (66.7%) with displacement had horizontal metamorphopsia vs 62 of 117 patients (53.0%) without displacement (13.7% difference; 95% CI, −5.5% to 32.8%; $P = .18$). Aniseikonia testing was performed in 142 of 238 patients (59.7%), all of whom were from St Michael's Hospital/Unity Health Toronto; of these, 103 patients (72.5%) had PR and 39 patients (27.5%) had PPV. Aniseikonia was present in 15 of 29 patients (51.7%) in the group with displacement vs 54 of 113 patients (47.8%) in the group without displacement (3.9% difference; 95% CI, −16.4% to 24.3%; $P = .70$).

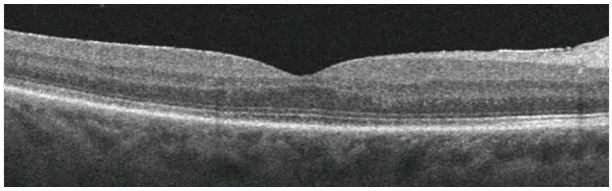
Mean (SD) postoperative logMAR visual acuity was 0.31 (0.32) (Snellen equivalent 20/40) in 134 eyes that initially underwent PR and 0.56 (0.42) (Snellen equivalent 20/72) in 84 eyes that underwent PPV (−0.25 difference; 95% CI, −0.14 to −0.35; $P < .001$). Mean postoperative logMAR visual acuity was 0.57 (0.46) (Snellen equivalent 20/74) in 55 eyes that had retinal displacement vs 0.35 (0.34) (Snellen equivalent 20/45) in 166 eyes that did not have retinal displacement (0.22 difference; 95% CI, 0.11-0.33; $P < .001$). Among eyes with displacement, mean postoperative logMAR visual acuity was 0.42 (0.42) (Snellen equivalent 20/52) in 20 eyes that initially underwent PR and 0.66 (0.47) (Snellen equivalent 20/91) in 33 eyes that initially underwent PPV (−0.24 difference; 95% CI, −0.48 to 0.01; $P = .07$).

Figure 1. Fundus Autofluorescence (FAF) and Optical Coherence Tomographic (OCT) Imaging After Pars Plana Vitrectomy (PPV) and Pneumatic Retinopexy (PR)

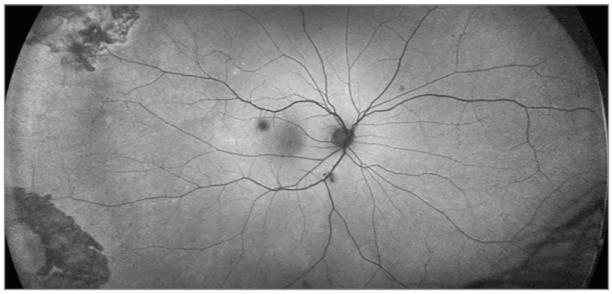
A FAF showing retinal vessel printing following pars plana vitrectomy



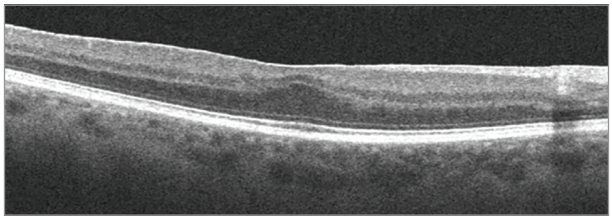
B OCT showing interdigitation zone disruption



C FAF showing no retinal displacement following pneumatic retinopexy



D OCT showing no outer retinal disruption



Fundus autofluorescence following PPV demonstrating retinal vessel printing (arrowheads) (A), OCT imaging showing interdigitation zone disruption (B), FAF following PR with no retinal displacement (C), and OCT imaging showing no outer retinal disruption (D).

Fifty-five of 57 eyes (96.5%) with displacement had interdigitation zone abnormalities on the 6-mm optical coherence tomographic scan vs 135 of 162 patients (83.3%) eyes without displacement (13.2% difference; 95% CI, 5.7%-20.6%; P = .01). Detailed optical coherence tomographic analysis and functional outcomes are presented in **Table 3**.

Discussion

Gross retinal reattachment is a crude measure of surgical success. There have been few attempts to date to compare alignment and structural integrity of retinal reattachment achieved between different procedures and techniques. We used fundus autofluorescence and optical coherence tomographic imaging postoperatively to assess the integrity of retinal reattachment. We define the terms *high-integrity retinal reattachment* and *low-integrity retinal reattachment* based on the absence or presence of retinal vessel printing on fundus autofluorescence imaging. High-integrity retinal reattachment is achieved by the retina being reapposed as close as possible to its original location with no retinal vessel printing shown on fundus autofluorescence imaging, which presumably indicates an alignment of photoreceptors closer to their original position relative to their specific retinal pigment epithelium cell. This proper alignment may allow for better photoreceptor function and superior functional outcomes. This study suggests that patients with high-integrity retinal reattachment are less likely to experience vertical metamorphopsia compared with those with low-integrity retinal reattachment.

Relatively high rates of retinal displacement following PPV have been reported.[2-4,6,7] Practice surveys demonstrate that most retinal surgeons drain either through the peripheral retinal break or a posterior retinotomy, with only 16.3% of surgeons routinely using perfluorocarbon liquid.[8] The surgical techniques used in this study therefore reflect real-world practice. Shiragami et al[2] documented inferior displacement in 62.8% of patients, with 69.8% of patients having undergone perfluorocarbon liquid-assisted drainage through the responsible break. They found that primary break location and perfluorocarbon liquid use did not appear to affect retinal displacement. It was also noted that patients were often upright for a few minutes before lying face down, which could have led to a gravity-induced downward displacement of residual subretinal fluid and the retina. Shiragami et al[9] subsequently reported that immediate face-down positioning led to a reduction in the proportion of patients with retinal displacement from 63.6% to 24.0% (P = .004).

Patients can be unsatisfied following rhegmatogenous retinal detachment repair, despite successful retinal reattachment and excellent visual acuity. We found that patients with retinal displacement were more likely to have vertical metamorphopsia compared with patients without displacement. Other studies have assessed the visual disturbances associated with retinal displacement. Lee et al[4] found macular displacement in 72% of macula-off rhegmatogenous retinal detachment and 29% of macula-on rhegmatogenous retinal detachment treated with PPV, with a significant correlation between displacement and symptoms of distortion. Pandya et al[6] reported downward displacement with PPV that was associated with visual symptoms. Other authors have also observed that variations in retinal displacement rates occur when using different tamponades. Codenotti et al[7] found retinal displacement in 12 of 23 eyes (52.2%) that underwent PPV, with

Table 2. Retinal Displacement for Pneumatic Retinopexy vs Pars Plana Vitrectomy as the Final Procedure for Reattachment

Characteristic	Pneumatic retinopexy		Pars plana vitrectomy		*P* value	Difference, % (95% CI)
	Total No.	No. (%)	Total No.	No. (%)		
Presence of retinal vessel printing						
Overall	114	8 (7.0)	124	55 (44.4)	<.001	37.4 (27.4-47.3)
Macula						
On	36	2 (5.6)	35	10 (28.6)	.01	23.0 (6.3-39.7)
Off	78	6 (7.7)	89	45 (50.6)	<.001	42.9 (30.9-54.8)
Direction of displacement	8		55		<.001	69.5 (38.9-100.0)
Inferior		2 (25.0)		52 (94.5)	NA	NA
Superior		6 (75.0)		3 (5.5)		
Zone 1 displacement	8	5 (62.5)	55	50 (90.9)	.02	28.4 (−6.0 to 62.8)

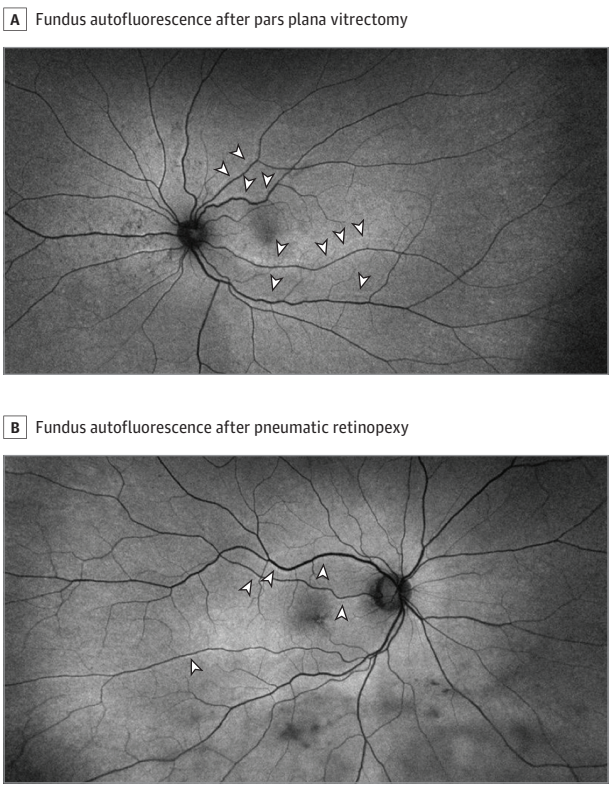
Abbreviation: NA, not applicable.

higher rates in procedures that used gas tamponades (10 of 14 [71.4%]) compared with silicone oil (2 of 9 [22.2%]). Dell'Omo et al[10] noted that 14.3% of patients with silicone oil had displacement compared with 41.2% of those who received sulfur hexafluoride. The investigators did not find that the use of perfluorocarbon liquid or posterior retinotomy reduced the occurrence of retinal displacement. Although displacement rates would appear to be reduced with silicone oil tamponade in these studies, silicone oil was used infrequently in our study.

This study suggests that the anatomic integrity of retinal reattachment can vary depending on the surgical treatment chosen. Retinal displacement may occur more frequently with PPV (44.4%) compared with PR (7.0%). Not only was displacement more common with PPV, the extent of the displacement in the macula was more severe with PPV. Displacement was usually in the superior direction with PR and inferior direction with PPV. Our displacement rate among patients who underwent PPV with gas is consistent with the literature.[10] We also found no meaningful difference in retinal displacement based on drainage method or type of gas tamponade in eyes that underwent PPV.

In addition to the presence and absence of vitreous, one difference between PR and PPV is that, in PR, there is a natural reabsorption of subretinal fluid by the retinal pigment epithelium pump compared with the forced internal drainage during PPV. Furthermore, PR involves the use of a small gas bubble with no air-fluid exchange, compared with air-fluid exchange and near 100% gas fill with PPV. There are also differences in positioning between the 2 procedures. We hypothesize that the natural reabsorption of subretinal fluid by retinal pigment epithelium in PR, together with the reduced buoyant force of a smaller gas bubble that is in contact with a smaller area of the retina, causes relatively less displacement of subretinal fluid and less retinal displacement (**Video 1**). Conversely, in PPV, a larger buoyant force is exerted on a larger area of relatively mobile retina resulting in greater subretinal fluid flux and retinal displacement (**Video 2** and **Video 3**). Extrapolating our findings to PPV techniques, we hypothesize that a smaller final gas bubble volume and allowing a significant proportion of the subretinal fluid to reabsorb naturally may be preferable to traditional PPV techniques.

Figure 2. Comparison of the Extent and Direction of Retinal Displacement



A, Fundus autofluorescence following pars plana vitrectomy for macula-off rhegmatogenous retinal detachment repair demonstrating retinal vessel printing (arrowheads) and large inferior displacement. B, Fundus autofluorescence following pneumatic retinopexy for macula-off rhegmatogenous retinal detachment repair demonstrating retinal vessel printing (arrowheads) and minimal superior displacement.

Limitations

This study has limitations. One limitation of this pragmatic study is the retrospective design, which may have allowed for unanticipated and unknown bias in the data set, and prospective studies will be helpful to corroborate our findings. However, we addressed potential bias. First, the primary outcome, the presence or absence of retinal vessel printing, was

Table 3. Optical Coherence Tomographic Imaging and Functional Outcomes Between Patients With and Without Retinal Displacement

Outcome	Displacement[a]				*P* value
	With		Without		
	Total No.	No. (%)	Total No.	No. (%)	
Optical coherence tomographic imaging					
Cystoid macular edema	59	13 (22.0)	166	26 (13.9)	.15
Normal foveal contour	60	34 (56.7)	165	110 (66.7)	.17
Subretinal fluid	60	6 (10.0)	165	24 (14.5)	.38
ERM grade					
No.	63		175		
No ERM		25 (39.7)		88 (50.3)	
0		7 (11.1)		29 (16.6)	
1		25 (39.7)		43 (24.6)	.28
2		3 (3.2)		7 (4.0)	
3		3 (4.8)		5 (2.9)	
4		1 (1.6)		3 (1.7)	
Retina folds 3 mm					
Inner	60	0	164	1 (0.6)	.54
Outer	60	0	164	3 (1.8)	.29
Choroidal folds 3 mm	60	0	165	1 (0.6)	.55
Retina folds 6 mm					
Inner	60	0	163	1 (0.6)	.54
Outer	60	1 (1.7)	163	8 (4.9)	.28
Choroidal folds 6 mm	60	0	164	1 (0.6)	.54
External-limiting membrane 3 mm	57	25 (43.9)	153	51 (33.3)	.16
Inner segment/outer segment 3 mm	58	38 (65.5)	158	81 (51.3)	.06
Interdigitation zone 3 mm	57	54 (94.7)	161	134 (83.2)	.03
Retinal pigment epithelium 3 mm	59	1	165	1 (0.6)	.55
External-limiting membrane 6 mm	56	11 (19.6)	147	34 (23.1)	.59
Inner segment/outer segment 6 mm	58	13 (22.4)	157	37 (22.6)	.86
Interdigitation zone 6 mm	57	55 (96.5)	162	135 (83.3)	.01
Retinal pigment epithelium 6 mm	60	1 (1.7)	164	0	.1
Functional					
Visual acuity, mean (SD), logMAR	55	0.57 (0.46)	166	0.35 (0.34)	.002
Snellen equivalent		20/74		20/45	
Metamorphopsia					
Vertical	30	25 (83.3)	117	65 (55.6)	.005
Horizontal	30	20 (66.7)	117	62 (53.0)	.18
Aniseikonia	29	15 (51.7)	113	54 (47.8)	.7

Abbreviation: ERM, epiretinal membrane.

[a] The numbers for some variables differ because poor-quality scans limited image interpretation.

assessed by 2 graders masked to treatment group. We also performed several subgroup and sensitivity analyses comparing primary PPV with PR that appeared to support the findings. We also suggest that displacement in PR vs PPV was not related to variations in surgical technique, such as method of drainage or type of gas. These additional analyses may substantiate the primary outcome of this study: patients undergoing PPV are at higher risk of low-integrity retinal reattachment compared with patients undergoing PR. Consistent with the findings of Shiragami et al,[9] who suggested that immediate face-down positioning of the patient reduced the frequency of retinal displacement, all but 4 patients in our PPV group had immediate face-down positioning. Because only 9 eyes in our study received perfluorocarbon liquid-assisted drainage, we cannot comment on the influence of heavy liquid on retinal displacement. There are conflicting data in the literature, with displacement rates ranging from 13% to 63.6% with perfluorocarbon liquid use. Nevertheless, recent practice trend surveys demonstrate that only 16.3% of retinal surgeons use perfluorocarbon liquid routinely in North America,[8] and hence the surgical techniques used in this study are representative of those currently used by most retinal surgeons.

Conclusions

Retinal displacement and low-integrity retinal reattachment appear to occur more frequently and are more severe with PPV vs PR. This study suggests a difference in anatomic integrity of retinal reattachment achieved with different surgical pro-

cedures, by comparing retinal displacement assessed by retinal vessel printing on fundus autofluorescence imaging. Recognition of the importance of retinal displacement and integrity of retinal reattachment (high-integrity vs low-integrity retinal reattachment) may lead to further refinements in vitreoretinal surgery techniques for primary rhegmatogenous retinal detachment repair and potentially improved functional outcomes for patients.

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Author Affiliations: Unity Health Toronto, Department of Ophthalmology, St Michael's Hospital, Toronto, Ontario, Canada (Brosh, Francisconi, Juncal, Berger, Giavedoni, Wong, Altomare, Marafon, Muni); Department of Ophthalmology & Vision Sciences, University of Toronto, Toronto, Ontario, Canada (Brosh, Francisconi, Juncal, Berger, Giavedoni, Wong, Altomare, Marafon, Muni); Hamilton Regional Eye Institute, St Joseph's Healthcare Hamilton, Division of Ophthalmology, Department of Surgery, McMaster University, Hamilton, Ontario, Canada (Qian, Chaudhary); Newcastle Eye Centre, Royal Victoria Infirmary, Newcastle upon Tyne, UK (Sabatino, Hillier, Kadhim, Newsom); Translational and Clinical Research Institute, Newcastle University, Newcastle upon Tyne, UK (Hillier); Kensington Vision and Research Center, Toronto, Ontario, Canada (Muni).

Author Contributions: Drs Brosh and Francisconi contributed equally to this manuscript. Drs Brosh and Muni had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Brosh, Francisconi, Hillier, Chaudhary, Berger, Muni.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Brosh, Francisconi, Qian, Hillier, Chaudhary, Newsom, Marafon, Muni.
Critical revision of the manuscript for important intellectual content: Brosh, Francisconi, Qian, Sabatino, Juncal, Hillier, Berger, Giavedoni, Wong, Altomare, Kadhim, Muni.
Statistical analysis: Francisconi, Qian, Juncal, Chaudhary, Altomare, Muni.
Administrative, technical, or material support: Brosh, Francisconi, Qian, Sabatino, Juncal, Hillier, Berger, Giavedoni, Wong, Kadhim, Newsom, Marafon, Muni.
Supervision: Hillier, Chaudhary, Wong, Muni.

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