PNEUMATIC RETINOPEXY (PR) was first introduced in the mid-1980s, independently by Dominguez1 and by Hilton and Grizzard,2 for the repair of rhegmatogenous retinal detachment (RRD). It consists of retinopexy of retinal breaks with intravitreal injection of gas into the vitreous cavity followed by postoperative positioning. Indications for PR, as described by Tornambe and Hilton3 in the multicenter, randomized, controlled clinical trial comparing PR with scleral buckling, included the presence of 1 or more retinal breaks within 1 clock-hour of the retinal arc in the upper two-thirds of the retina and sufficiently clear media to rule out the presence of other retinal breaks. Later on, indications for surgery have expanded to include multiple breaks in multiple quadrants, larger retinal breaks, and moderate proliferative vitreoretinopathy (PVR).4,5 With time, owing to its minimally invasive nature, cost-effectiveness, and relatively technical simplicity, PR has become commonly used in clinical practice. However, alongside its widespread popularity, the reported complications associated with PR have also grown.6-13 In addition, PR was reported to be less efficient in specific conditions, including in nonphakic eyes, in eyes with poor preoperative visual acuity (VA), in large detachments, and in cases with multiple retinal breaks.7,13-15 Furthermore, a broad range of anatomical success rates of 53% to 100% after a single PR procedure were reported.12 Together these reservations gave rise to a heated debate between those in favor and those against PR for RRD. The objective of this study was to investigate, in a relatively large case-series, the risk factors for failure and outcomes of PR surgery for the repair of primary RRD, with special attention to differences in out-
comes between successful cases and failed cases that underwent only 1 additional reattachment operation.

METHODS

STUDY DESIGN

The medical records of patients who underwent PR for primary RRD in The Goldschleger Eye Institute, The Sheba Medical Center, Tel Aviv, Israel, were reviewed retrospectively. The review period extended from January 1, 2000, through June 30, 2011. Inclusion criteria were primary RRD, PR as the primary procedure, and a follow-up period of at least 2 months. Two months' limit was chosen because by this time the gas bubble is fully absorbed.

These data retrieved from the medical records included the following: age, sex, ocular history, laterality, duration of symptoms, axial length, spherical equivalence, preoperative clinical examinations, intraoperative data, and follow-up examination results, additional surgical procedures needed, and complications. The extent of the detachment was marked in clock-hours, the number and location of breaks and the involvement of the macula were also noted. Retinal breaks were defined as inferior if located between 4- and 8-o'clock positions (via the 6-o'clock position). All other breaks were defined as upper temporal or upper nasal.

Patients with less than 4 months' follow up were contacted and invited for examination to obtain longer follow up. At this examination, the ocular history since his or her last visit was obtained, and he or she underwent a full ophthalmic examination. Patients who could not come or refused to be reexamined were asked to provide details of their follow up. In case they did not have a detailed medical report, we asked permission to contact the clinic at which they were followed up and retrieve their data. All telephone calls were executed by 2 investigators (I.D.F. and M.E.). The study protocol was approved by the local institutional review board and in concordance with the Declaration of Helsinki.

STUDY DEFINITIONS

Success: Attached retina at least 2 months after the PR without additional procedures.

Primary failure: Retinal redetachment within 2 months from PR or persistent retinal detachment after PR, which required an additional reattachment procedure.

Late retinal redetachment: Retinal redetachment after successful reattachment, observed at least 2 months after the PR.

Single surgery anatomical success (SSAS): Reattachment of the retina with PR, not requiring any additional retinal procedures until the end of the follow-up period.

Final anatomical success: attached retina at the final follow-up visit.

SURGICAL TECHNIQUE

All procedures were executed under subconjunctival anesthesia. Pneumatic retinopexy was performed using a technique similar to that previously described by Hilton and Grizzard. After transconjunctival cryoexy to the retinal breaks, 0.3 to 0.4 mL of perfluoropropane gas was injected intravitreally. Drainage of aqueous from the anterior chamber was performed either before or after the gas injection by some of the surgeons. Postoperatively, the patients were positioned so that the gas bubble adequately covered the retinal breaks. In addition, selected patients underwent postoperative laser retinopexy to the retinal breaks.

STATISTICAL ANALYSIS

The operations were performed by 7 vitreoretinal surgeons. Three surgeons (A.A., H.D., and J.M.) performed most of the procedures (85, 73, and 49), and together the other 4 performed the remaining 49 procedures. A comparison between surgeons regarding success rates and outcomes was performed, but the 4 surgeons with the lower volume were grouped and were considered as a single group.

All calculations were performed and presented using commercially available software (Microsoft Excel 2007; Microsoft Corporation) and SPSS software, version 17.0 (SPSS, Inc). The t test was used to compare parametric data. Nonparametric data were analyzed with χ2 testing unless an expected cell count was less than 5, in which case the Fisher exact test was used.

Snellen VA was converted to a logarithm of the minimum angle of resolution (logMAR) equivalent. Approximations for VA worse than 20/400 were as follows: counting fingers, 20/2000; hand motions, 20/4000; light perception, 20/8000; and no light perception, 20/16000.16 Statistical significance was set at P<.05. Data are presented with 1 SD throughout the article.

RESULTS

Two hundred seventy-six eyes of 271 patients underwent PR during the study period. Of these, full data was obtained on 258 eyes (93.5%) of 253 patients, and they were included in the study series. Only 18 eyes (6.5%) of 18 patients were excluded from analysis because of short follow-up or lack of data.

Of the 253 patients, 60.9% were males and 39.1% were females. The mean (SD) age was 57.3 (12.2) years (age range, 16.0-83.0 years), with a mean (SD) follow-up time of 36.1 (39.4) months (range, 2.0-141.0 months). One hundred forty-eight eyes (57.4%) were followed up for at least 1 year. Only 23 eyes (8.9%) had a follow-up shorter than 4 months. In all eyes, retinal breaks were detected in the superior two-thirds of the fundus. In 72.4% of eyes, a break was found in the upper temporal retina and in the upper nasal retina in 27.6% of eyes. The mean (SD) number of breaks was 1.2 (0.5) (range, 1-5 breaks) in a total mean (SD) area of 1.1 (0.3) clock-hours (range, 1.0-2.0 clock-hours). None of the eyes had a significant vitreous hemorrhage.

Successful reattachment at 2 months was achieved in 171 (66.3%) of 258 eyes with only 1 additional operation. The other 87 eyes (33.7%) underwent additional operations for a new or persistent RRD. A single surgery anatomical success was achieved in 158 eyes (61.2%); final anatomical success was achieved in 256 eyes (99.2%).

Of the 87 eyes with primary failure, 67 eyes (77.0%) were reattached with 1 additional operation only: PPV with gas injection (31 eyes), scleral buckle (30 eyes), PR (2 eyes), and PPV with silicone oil injection (4 eyes). Seventeen eyes (19.5%) underwent 2 additional operations, and 3 eyes (3.4%) underwent 4 additional reattachment operations. The type and order of surgical procedures for patients who underwent more than 1 additional operation are shown in the Figure. The second reattaching operation was performed within a mean time of 22.8 (19.9) days (range, 1-83 days) after the primary PR. Three of the failed cases were reoperated on beyond the 60 days limit (70, 80, and 83 days); however, they
were considered primary failure because they had a persistent local RRD from the primary PR. Five eyes (2.0%) have developed PVR and subsequently underwent PPV with retinectomy and silicone oil injection.

Late redetachment occurred in 12 eyes (4.7%). Of these, 10 eyes (83.3%) underwent only 1 additional reattachment operation (2 PPV with perfluoropropane gas injections, 4 scleral buckles, and 4 PRs) and 2 eyes (16.7%) underwent 2 additional reattachment operations (Figure). In the late redetachment group, the mean time of reoperation was 301.5 (343.1) days (range, 68-1250 days) after the primary PR. In all cases but 1, a new retinal break was diagnosed. In most cases, the new break was found within 90/11034 from the original break. Only 1 patient with PVR underwent PPV and retinectomy.

Comparison of the outcome of PR procedures performed by the 3 higher volume surgeons (A.A., H.D., and J.M.) and the group including the combined results of the surgeons with the lower volume revealed no statistically significant difference between surgeons for the rate of PR failure, the rate of postoperative complications, or final VA (P= .975).

SUCCESS VS PRIMARY FAILURE

Preoperative characteristics of the successful and failed PR cases are summarized in Table 1. Patients with failed PR were, on average, 3.7 years younger compared with the successful PR group (54.9 vs 58.6 years for the primary failure PR and successful cases, respectively; P=.02). Approximately one-fifth of both groups were pseudo-
In contrast to the significantly worse outcome and high complication rate of the whole primary failure group (n = 87), this group had a better outcome. The final logMAR was found to be a risk factor for failure (88.8% vs 76.2% of the successful and primary failure PR cases, respectively; P = .04). Absence of intact posterior capsular bag (due to a tear or prior posterior capsulotomy) was not found to be a risk factor for failure (88.8% vs 76.2% of the successful and primary failure PR cases, respectively; P = .18). The total size of breaks was found to be slightly, though significantly, smaller for the primary failure group (1.2 vs 1.1 clock-hours for the successful and primary failure PR cases, respectively. P = .027). Compared with the successful PR group, the primary failure group had worse final VA (logMAR 0.2 and 0.4 for the successful and primary failure PR cases, respectively; P = .002) and substantially more postoperative complications, including epiretinal membrane (P < .001), cystoid macular edema (P = .03), and PVR (P = .001). There was also a nonsignificant trend toward the development of more postoperative cataract in the failure group (24.6% and 36.8% for the successful and primary failure PR cases, respectively; P = .057), and more eyes in this group underwent cataract surgery during the follow up (17.3% and 30.7% for the successful and primary failure PR cases, respectively; P = .02). In the failure group, 59.3% eyes that later developed cataract underwent a vitrectomy procedure.

### SUCCESS VS PRIMARY FAILURE WITH ONLY ONE ADDITIONAL REATTACHMENT OPERATION

Table 2 compares the outcomes of the successful PR group and the primary failure group which underwent only 1 additional retinal reattachment procedure (n = 67). In contrast to the significantly worse outcome and high complication rate of the whole primary failure group (n = 87), this group had a better outcome. The final logMAR for this group was only slightly worse than that of the successful group (logMAR 0.2 and 0.3 for the successful and primary failure PR cases, respectively; P = .03). Moreover, no statistical differences were noted in the delta logMAR (difference between logMAR at presentation and final logMAR) between the 2 groups (0.46 vs 0.35 for the successful and primary failure PR cases, respectively; P = .38). The data in Table 2 indicate that there was no difference in the rate of development of macular hole, cystoid macular edema, PVR, and cataract, in this group compared with the successful group. There were more cases of epiretinal membrane in this group (11.3% and 23.5% for the successful and primary failure PR cases with only 1 additional operation, respectively; P = .03); however, it had an insignificant impact on final VA (final logMAR 0.22 and 0.25 for patients who developed epiretinal membrane in the successful and primary failure PR groups with only 1 additional reattachment procedure, respectively; P = .11).

### SUCCESS VS PRIMARY FAILURE WITH 2 OR MORE ADDITIONAL REATTACHMENT OPERATIONS

Patients who required 2 or more additional operations had a significantly worse outcome (Table 2) than the successful cases or those that required only 1 additional procedure to reattach the retina. Specifically, the patients who required 2 or more additional operations had worse final VA (final logMAR 0.67 and 0.20 for the failed group with ≥2 additional operations and successful group, respectively; P = .015), and significantly more cases of epiretinal membrane, cystoid macular edema, PVR, cataract operations, and additional nonretinal operations (P < .004).

### COMMENT

In this retrospective analysis, successful retinal reattachment after PR surgery for primary RRD was achieved in 66.3% of the cohort. Success rates reported in the published literature are found in a very wide range. Hilton et al2 and Tornambe17 reviewed data of nearly 1300 PR

<table>
<thead>
<tr>
<th>Variable</th>
<th>Successful PR (n = 171)</th>
<th>Primary Failure Cases With 1 Additional Operation (n = 67)</th>
<th>P Value</th>
<th>Primary Failure Cases With 2 or More Additional Operations (n = 20)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LogMAR at final follow-up, mean (SD), Snellen VA</td>
<td>0.20 (0.30)</td>
<td>0.31 (0.37)</td>
<td>.03</td>
<td>0.67 (0.80)</td>
<td>.02</td>
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<tr>
<td>Macular hole development</td>
<td>1.8</td>
<td>2.9</td>
<td>.63</td>
<td>5.0</td>
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<tr>
<td>Cystoid macular edema development</td>
<td>11.3</td>
<td>23.5</td>
<td>.03</td>
<td>50.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Proliferative vitreoretinopathy development</td>
<td>2.4</td>
<td>5.9</td>
<td>.23</td>
<td>20</td>
<td>.004</td>
</tr>
<tr>
<td>Cataract development</td>
<td>24.6</td>
<td>34.3</td>
<td>.15</td>
<td>45.0</td>
<td>.05</td>
</tr>
<tr>
<td>Cataract operations</td>
<td>17.3</td>
<td>25.0</td>
<td>.20</td>
<td>50.0</td>
<td>.001</td>
</tr>
<tr>
<td>Additional nonretinal detachmentc</td>
<td>4.2</td>
<td>8.8</td>
<td>.20</td>
<td>40.0</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: PR, pneumatic retinopexy; RRD, rhegmatogenous retinal detachment.

a Data are given as percentage unless otherwise indicated.

b P value compared with the successful pneumatic retinopexy group.

c Including epiretinal membrane peeling, macular hole repair, silicone oil removal, and vitrectomy for vitreous hemorrhage.

- Phakic (21.4% and 23.9% of the successful and primary failure groups, respectively; P = .38). The pseudophakic primary failure group had a significantly longer time lag between cataract surgery and RRD (25.4 and 47.1 months for the successful and primary failure PR cases, respectively; P = .04). Absence of intact posterior capsular bag (due to a tear or prior posterior capsulotomy) was not found to be a risk factor for failure (88.8% vs 76.2% of the successful and primary failure PR cases, respectively, had an intact posterior capsule; P = .18). The total size of breaks was found to be slightly, though significantly, smaller for the primary failure group (1.2 vs 1.1 clock-hours for the successful and primary failure PR cases, respectively. P = .027). Compared with the successful PR group, the primary failure group had worse final VA (logMAR 0.2 and 0.4 for the successful and primary failure PR cases, respectively; P = .002) and substantially more postoperative complications, including epiretinal membrane (P < .001), cystoid macular edema (P = .03), and PVR (P = .001). There was also a nonsignificant trend toward the development of more postoperative cataract in the failure group (24.6% and 36.8% for the successful and primary failure PR cases, respectively; P = .057), and more eyes in this group underwent cataract surgery during the follow up (17.3% and 30.7% for the successful and primary failure PR cases, respectively; P = .02). In the failure group, 59.3% eyes that later developed cataract underwent a vitrectomy procedure.

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cases from 26 articles and reported a rate of 53% to 100% with a calculated average of 80%. Some of the articles included in their analysis are anecdotal (eg, a series of 4 eyes that underwent PR with success rate of 100%), whereas our case series is a large-scale cohort (258 eyes) operated on in a single medical center. Grizzard and colleagues performed a retrospective analysis on 107 consecutive eyes that underwent PR in their practice together with a literature review of 25 series on PR with primary attention to failures, and reported 69% single successes. Other publications reported success rates ranging from 62% to 68%, which are also in the range of our results. It is our belief that cases of primary failure should be analyzed separately from cases of late redetachment, which is the most common reason for failure of PR. However, this is not the case in all published reports. Kulkarni et al, similarly to our findings, found no significant differences in anatomical outcomes between phakic and pseudophakic eyes. Most clinical series on PR have shown higher success rates in phakic RRDs than in pseudophakic RRDs. It is believed that the reason is increased incidence of missed breaks, which is the most common reason for failure of PR. However, this is not the case in all published reports. Kulkarni et al similarly to our findings, found no significant differences in anatomical outcomes between phakic and pseudophakic eyes (24.7% and 22.4% underwent an additional reattachment operation after primary PR; \( P = .79 \)). It is likely that pseudophakic status is not a contraindication for PR, and that the anatomical outcome is as good in these eyes as in phakic eyes. A meticulous search for retinal breaks should be performed in all eyes, and especially in pseudophakic ones. In our case series absence of intact posterior capsule did not correlate with failure. These findings correspond with some published series, but differ from others. In contrast to published articles, we found no associations between sex, worse initial VA, total area of detachment, macular status (detached or attached), and failure of PR.

Mudvari et al reported 50 cases of redetachment after primary PR. Most of their clinical descriptive data are similar to that of the failed cases in our cohort, but they included in their analysis cases of both early and late redetachment (redetachment up to 161 days after PR). It is our belief that cases of primary failure should be analyzed separately from cases of late redetachment, which are actually successful PR cases that redetached later. Most patients in their cohort (76%) redetached in the first month, thus, according to our criteria are defined as primary failure.

As mentioned earlier, when compared with the success group, the primary failure group had significantly more postoperative complications and worse final VA. These differences, however, became indistinct when a sub-analysis was performed, comparing the success group with the primary failure cases that underwent only 1 additional reattachment procedure (77.0% of the failed eyes).

No differences were found for the development of macular hole, cystoid macular edema, or PVR. Epiretinal membrane was shown to develop more in the failure group, but its presence was clinically insignificant, that is, no differences in the final VA between groups. Only a minor, although statistically significant, difference was found between the 2 groups for the final VA. Furthermore, no statistical differences were found between groups in the delta between VA at presentation and at the final follow-up. As both groups were seen with approximately the same mean VA, one can conclude that VA of the success group did not improve to a better extent, compared with the primary failure group that underwent only 1 additional operation. The mean final VA of primary failure cases that underwent only 1 additional operation was 20/41, similar to that of the whole study cohort (20/37), and 45 (66.2%) of these eyes attained a VA greater than 20/40. Our findings emphasize the concept that in most cases failure of the PR does not adversely affect the potential for visual recovery. Only 20 eyes (23.0% of the primary failure group and 7.8% of the whole cohort) underwent more than 1 additional reattachment procedure, and they achieved a final VA of 20/94. This low rate of eyes with more complications and more additional operations is similar to that reported after all primary reattachment procedures.

Late redetachments occurred in 4.7% of the cases. As mentioned earlier, in all cases but one a new retinal break was diagnosed. It is possible but not likely that the perfluoropropane gas bubble had a role in inducing these new breaks, as the mean time to redetachment occurred long after the perfluoropropane gas bubble was absorbed (301.5 days after the primary RD).

The major limitations of our study include its retrospective nature and the use of Snellen charts for VA determination. The strengths of the case series include its large sample size and the fact that we were able to retrieve reliable and detailed data about 92.8% of cases that underwent PR surgery in the study period. To our knowledge, this poses the current study as one of the largest reported cohorts.

In summary, our study demonstrates that with proper selection of cases PR is a good surgical option for primary RRD. In two-thirds of cases, the retina will be attached after the procedure. The rest of the cases will require additional reattachment operations, most of which will reattach with only 1 additional operation and will also have good anatomical and functional outcomes.

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Conflict of Interest Disclosures: None reported.

Online-Only Material: This article is featured in the JAMA Ophthalmology Journal Club. Go to http://www.jamaophthalmology.com to download teaching PowerPoint slides.
REFERENCES


Web Quiz Winner

Congratulations to the winner of our September quiz, Aditi Gupta, MS, DNB, Department of Vitreo-Retina, EyeQ Superspeciality Eye Institute, Gurgaon, India. The correct answer to our September challenge was grade 4 familial (autosomal recessive) isolated foveal hypoplasia. For a complete discussion of this case, see the Small Case Series section in the October issue (Saffra N, Agarwal S, Chiang JPW, Masini R, Bertolucci A. Spectral-domain optical coherence tomographic characteristics of autosomal recessive isolated foveal hypoplasia. Arch Ophthalmol. 2012;130[10]:1324-1327).