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Anatomic, Visual and Financial Outcomes for Traditional and Nontraditional Primary Pneumatic Retinopexy for Retinal Detachment

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Abstract

Purpose: To determine factors predictive of anatomic, visual and financial outcomes after traditional and nontraditional primary pneumatic retinopexy (PR) for rhegmatogenous retinal detachment (RD).

Design: Retrospective interventional case series and cost comparison

Methods:

Participants: 178 eyes (156 patients) with PR-repaired primary RD by a single surgeon at a clinical practice from 1/2001–12/2013 and followed for ≥1 year. The cohort had 2 sub-groups: traditional (TPR) and nontraditional (NTPR) PR.

Main Outcome Measures: Characteristics associated with best corrected visual acuity (BCVA) and anatomical outcomes. Cost analysis and potential cost savings comparing PR to scleral buckle and vitrectomy.

Results: 131 of 178 eyes (73.5%) were successfully treated at 1 year (POY1): 72.8% (75/103) in TPR and 74.6% (56/75) in NTPR. Macula-off detachment (−0.44logMAR, p<0.001) and clock hours of RD (−0.84logMAR, p<0.001) correlated with improved BCVA; pseudophakia (0.26logMAR, p=0.002) and inferior retinal tears (0.62logMAR, p=0.009) correlated with

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worsening BCVA. Pseudophakia (−0.15, p=0.03), inferior quadrant RD (−0.27, p<0.001) and proliferative vitreoretinopathy (−0.68, p<0.001) correlated with anatomic failure. Total average cost for TPR and NTPR was $1248.37±882.11 and $1471.91±942.84, respectively (p=0.10). PR had a potential cost savings of 62% and 60.8% when compared to scleral buckle and vitrectomy, respectively.

Conclusions: PR results in successful anatomic and visual outcomes in both TPR and NTPR repair of primary RD. Preoperative pseudophakia is associated with worse visual outcomes and less anatomical success. The cost of primary PR and subsequent procedures to achieve final anatomic success was not significantly different between TPR and NTPR, and supports the possible cost-effectiveness of expanded indications for PR.

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Pneumatic retinopexy results in successful long-term anatomic and visual outcomes in both traditional and nontraditional cases of primary rhegmatogenous retinal detachment and demonstrates significant cost-savings with no difference between the two in overall cost.

Introduction

Pneumatic retinopexy (PR) was first described by Hilton and Grizzard in 1986[1] as a surgical treatment for primary rhegmatogenous retinal detachment (RD) and has subsequently been well studied as a primary treatment,[2, 3] as well as a rescue treatment in patients with failed primary RD surgery.[4] There is a large body of literature on the possible indications and relative contraindications for PR.[5–26] This surgery remains a useful office-based procedure for treating certain types of primary RDs and has single-surgery success rates ranging from 45–90 %, depending on the surgeon and cases selected.[26, 27] Ideal case selection typically includes uncomplicated RDs with retinal breaks in the superior 8 clock hours or multiple superior breaks confined to a single clock-hour of the retina and sufficiently clear media.[2, 28] Expanded indications with similar successful outcomes have included multiple quadrants of RD, larger retinal breaks, moderate proliferative vitreoretinopathy, mild vitreous hemorrhage, extensive lattice degeneration, bridging vessels, inferior retinal breaks, greater than 1 retinal break separated by greater than 1 clock hour, visible traction on the retinal break, retinal breaks in both detached and attached retina, and absence of identifiable breaks.[25,29] In cases of PR failure, studies have shown that a majority of eyes were reattached with only 1 additional operation and had final anatomical and visual success in almost 99.2 % of cases.[30]

Previous reports have analyzed predictive factors for successful visual and anatomical outcomes in large multicenter[2] and tertiary hospitals in which study cohorts are composed of patients who underwent PR by one of multiple possible surgeons.[12,27, 28, 30–33] However, there has been no previous long-term study on PR involving a single surgeon. By incorporating multiple surgeons, more data can be collected and analyzed, but this may also introduce variability in surgical technique. For example, surgeons may choose to perform primary cryotherapy and/or laser photocoagulation differently, or may utilize different types of gas (sulfur hexafluoride versus perfluoropropane). These variations could result in confounding variables that may affect the predictive outcomes of anatomical and visual

success. Analysis of a single surgeon's PR outcomes and case selection with fewer variables for the non-traditional cases has the potential to expand on the types of cases that could be successfully treated with PR.

Herein, we conducted a single-surgeon, retrospective study between 2001 and 2015 on patients who had at least 1 year of postoperative follow up to determine factors predictive of long-term visual, anatomic, and financial outcomes after PR repair of treatment-naive RD. Our main cohort was divided into two classifications: (1) traditional pneumatic retinopexy (TPR), or (2) nontraditional pneumatic retinopexy (NTPR), dependent on preoperative characteristics. Baseline characteristics potentially associated with primary PR best corrected visual acuity (BCVA) outcomes at postoperative year (POY) 1 and POY3, with anatomical outcomes at POY1 evaluated for both groups, as well as differences in visual and anatomic outcomes analyzed. Furthermore, a cost analysis comparison of the two cohorts was organized based on data obtained from the Centers for Medicare and Medicaid Services (CMS) reimbursement current procedural terminology (CPT) codes, with the purpose of elucidating the potential cost savings of PR in both traditional and nontraditional cases.

Methods

Institutional Review Board (IRB) approval was obtained from the Western IRB (Olympia, WA, USA) for this Health Insurance Portability and Accountability Act-compliant, retrospective interventional case series and cost comparison study, and all research adhered to the tenets of the Declaration of Helsinki.

A single-center, retrospective study was performed on a consecutive series of 324 eyes with rhegmatogenous RD repaired by PR performed by a single surgeon (DAB) from January 2001 to January 2015 at East Bay Retina Consultants, Inc., California (CA) with available medical records. A vast majority of treatment-naïve, primary RDs without giant retinal tear (GRT), substantial proliferative vitreoretinopathy (PVR) or limited visualization of the retina that seen by DAB are uniformly treated with PR as first-line treatment, including many with NTPR preoperative features. Additionally, eyes with previous RDs or history of prior surgeries for repair of RD or laser retinopexy for retinal tears were excluded from this study. Seventy-eight eyes with primary RDs with less than 1 year of follow-up were also excluded. In total, 178 eyes from 156 consecutive patients were included in the analysis.

Each PR was performed by DAB in a similar, regimented fashion. After thorough depressed examination to identify all causative breaks, retrobulbar anesthesia and akinesia was performed followed by cryoretinopexy to the retinal breaks. Depending on the size of the eye (myopic versus hyperopic) and phakic status, there was variability in the total amount of anterior chamber fluid that could be removed. Moreover, during manipulation of the eye during cryotherapy and depression, fluid from the posterior cavity was also manipulated forward in some cases. The volume of sulfur hexafluoride (SF6) injected was determined by adding 0.15 ml to the volume of fluid withdrawn from the anterior chamber. The anterior chamber tap was repeated before and after manipulation of the eye before cryotherapy and depression, which allowed time for AC refill and additional fluid removal. As such, an anterior chamber paracentesis was performed to remove 0.40–0.60 ml of aqueous fluid

followed by injection of 0.55–0.75 ml of 100 % SF6 via the pars plana. An additional post-gas injection anterior chamber paracentesis was also performed as needed to ensure central retinal artery perfusion. When indicated, additional laser or cryoretinopexy was performed at the surgeon's discretion for additional pathology not associated with the primary RD. If the primary RD was too bullous, additional cyroretinopexy or laser retinopexy was done within 1 week after the initial placement of the gas bubble.

The primary cohort was divided into 2 groups dependent on existing preoperative properties: traditional PR and nontraditional PR. Traditional PR was defined as having preoperative characteristics ideally indicated by Tornambe et al.[2] and Gilca et al.[28] These case selections typically include uncomplicated RDs with retinal breaks in the superior 8 clock hours or multiple superior breaks confined to a single clock-hour of the retina and sufficiently clear media.[2, 28] The definition of nontraditional PR employed in this study is a modification of the criteria originally defined by Goldman and colleagues[29] and include RDs that involve: multiple tears separated by greater than 1 clock hour apart; tears in flat or detached retina below the horizontal meridians defined at 8 and 4 o'clock; and/or mild to moderate vitreous hemorrhage. Anatomic and visual outcomes were analyzed based on these two groupings.

Primary outcome measures were POY1 PR anatomic success and POY1 and POY3 best-corrected visual acuity (BCVA) post-PR. Anatomic failure was defined as adjuvant surgical intervention for RD in the same eye (scleral buckle and/or vitrectomy, or additional PR) within 1 year after initial PR. Additional laser reinforcement, cryotherapy, or injection of additional gas within the week after initial PR was performed were not considered additional surgery for anatomical failure, but as a continuation of the original procedure. Patient clinical information and imaging data were assessed for baseline preoperative characteristics and postoperative complications related to RD repair. Postoperative complications included abnormally increased intraocular pressure, vitreous hemorrhage, macular pucker (clinically diagnosed and anatomically confirmed on optical coherence tomography, irrespective of visual significance), and proliferative vitreoretinopathy.

For statistical analysis, Snellen visual acuity was converted to logarithm of the minimum angle of resolution (logMAR). Counting fingers vision was converted to a value of 1.6 logMAR, hand motion vision was converted to a value of 1.9 logMAR and light perception vision was converted to a value of 2.2 logMAR. One of 178 eyes (0.5 %) had a baseline logMAR of 2.2. No cases worse than light perception vision were included in this study. Preoperative baseline characteristics potentially associated with POY1 primary PR anatomical outcomes and POY1 and POY3 BCVA outcomes were evaluated by Fischer exact test, 2-tailed t-test, univariate and multivariate regression. Statistical significance was set at $p < 0.05$.

Cost Analysis:

A comparative cost analysis (in United States dollars, USD) was made between the two cohorts one year after initial TPR or NTPR office-based procedure for repair of treatment-naive primary RD. Subsequent operating room procedures related to failure of the initial RD after primary PR repair at year one were also calculated, both in summation with and separate from initial PR costs. However, costs of elective operating room surgeries such as

macular pucker surgery or vitrectomy for floaters and vitreous debris were tabulated separately and not included in the cost analysis of the original surgical repair of the primary RD. Comparative cost analysis was performed by a two sample t-test of the two cohorts (TPR versus NTPR), using fee schedules provided by CMS reimbursement CPT codes. Fees were dependent on the date and location of the performed procedure. Outpatient office-based procedures followed CMS' reimbursement fees listed as "non-facility," while surgeries performed within an inpatient hospital or ambulatory surgical facility were obtained from "facility" labels. Statistical significance was set as $p < 0.05$.

CMS-listed National Payment Amounts were used from the year 2007 onwards for PR only (CPT code 67110), laser (67145), cryotherapy (67141), scleral buckle (67107) and pars plana vitrectomy (67108) for non-complex RD repair. CPT code 67110 entailed initial PR bundled with either laser treatment or cryotherapy procedure. CPT codes 67145 and 67141 correspond to subsequent laser treatment and cryotherapy procedures, respectively, after initial pneumatic retinopexy. Complex RD repair utilized CPT code 67113 from 2008 onwards. Prior to 2008, complex repair of RD was billed under CPT codes 67038 and 67108, and CMS data for this comparison analysis, with respect to complex RD repair, were utilized as such as necessary. Furthermore, between the years 2000 and 2006, fee schedules were dependent on specific Medicare Administrative Contractor (MAC) Locality as CMS National Payment Amounts (MAC Locality 0000000) were unavailable during the aforementioned dates. MAC Locality corresponding to the Oakland/Berkeley region (3114007) was used when National Payment Amount was not accessible, as this was the location where the initial PR was performed.

Elective operating room surgery costs were computed separately from initial PR costs and were not included in analysis for RD repair. These included CPT codes 67041 for pars plana vitrectomy with membrane peel for macular pucker (billed 2009 onwards), 67038 for pars plana vitrectomy with membrane peel for macular pucker (billed 2002–2008), and 67036 for vitrectomy for removal of vitreous debris.

Average potential total cost comparisons between nontraditional PR (CPT code 67110) and either scleral buckle (CPT code 67107) or vitrectomy with and without scleral buckle (CPT code 67108) were tabulated using CMS Physician Fee Schedule data from the year 2017. Fee schedules for surgeon, ambulatory surgical center, and anesthesia were provided by EyeMD, an outpatient ambulatory surgical center in Oakland, CA, USA. Utilizing the reoperation rates from the European Vitreo-Retinal Society (EVRS) Retinal Detachment Study Report,[34] we assumed a scleral buckle reoperation rate of 15.9 %, using the weighted average of Adelman et al.'s phakic and pseudophakic Level 3 failure group, defined as percentage of eyes that required an additional surgery after single repair using scleral buckle for primary RD. We also assumed a vitrectomy with or without buckle reoperation rate of 11.0 %, using the same methodology.[34] In this cost analysis, reoperations were assumed to be done with both vitrectomy with or without buckle, CPT code 67108, and repair of complex retinal detachment, with vitrectomy and membrane peeling, CPT code 67113.

Furthermore, we created a true cost comparison analysis between the TPR cohort, the NTPR cohort, and Total Surgeries, using data provided from our study. This analysis was based on

surgeries performed by DAB for each included eye, not by rates previously noted by the EVRS study report. “Total Surgeries” included initial PR, as well as all follow-up surgeries and adjuvant procedures, excluding cataract extraction/intraocular lens. Costs for this comparison were based off CMS Physician Fee Schedule data corresponding to the proper CPT codes at the time of surgery performed.

Results

Demographics

There were 178 eyes from 156 patients with treatment-naïve RD repaired by primary PR with SF6 gas by a single surgeon (DAB) that met the inclusion criteria. In terms of baseline demographic features (Table 1), the majority was male, 127 of 178 (71 %), with a greater proportion of the NTPR group being male (60/75, 80.0 %) than in the TPR group (67/103, 65 %, $p = 0.03$). In terms of laterality, the number of right and left eyes for the entire cohort was 98 and 80, respectively; with a greater proportion of right eyes in the TPR (64/103, 62.1 %) than the NTPR group (34/75, 45.3 %, $p = 0.03$). The mean age at time of initial PR was 55.9 (range 14–87); average time of follow-up was 57.5 months (std ±44.0, range 12–307); the average duration of symptoms prior to presentation was 10.1 days (std ±19.6, range 1–180 days); and 6.7 % (12/178) endorsed a recent history of ocular trauma. In terms of preoperative characteristics (Table 2), 70.2 % (125/178) were phakic; 40.4 % (72/178) were macula-off; the average number of total clock hours of RD was 4.0 (std ±2.1); the mean number of total breaks was 2.5 (std ±2.1); the mean number of breaks within the RD was 2.1 (std ±1.5) and the mean number of breaks in flat retina was 0.46 (std ±1.1); and 27.5 % (49/178) had lattice degeneration. There were significantly more mean number of retinal breaks identified in the NTPR versus TPR group (3.9 in NPTR vs. 1.6 in TPR, $p < 0.001$), with more retinal breaks identified both in detached retina (2.8 in NPTR vs. 1.5, $p < 0.001$) and in attached retina (1.1 in NPTR vs. 0, $p < 0.001$). In addition, there was more identified lattice degeneration in the NTPR versus the TPR group (28 (37.3 %) vs. 21 (20.3 %), $p = 0.01$).

All eyes were treated with PR with SF6 gas and the average amount of gas injected was 0.60 milliliters (std ±0.074, range 0.4–0.8, Table 2). Treatment modalities include cryotherapy in 65.7 % (117/178), laser retinopexy 9.0 % (16/178) and 25.2 % (45/178) with both. There was significantly more cryotherapy (83 (80.6 %) vs. 34 (45.3 %), $p < 0.001$) used in the TPR versus NTPR group. Combination of cryotherapy and laser retinopexy was used more frequently in the NTPR versus TPR group (31 (41.3 %) vs. 14 (13.6 %), $p < 0.001$). Table 3 details the preoperative characteristics for NTPR eyes.

Anatomic Outcomes

Primary anatomic success within 1 year after PR was achieved in 73.5 % (131/178) eyes. Final anatomic success including subsequent surgery for failed primary PR at last follow-up of up to 10 years was achieved in 98.9 % (176/178) eyes. Only two eyes failed to be successfully repaired, one in each subgroup. Thirty-five eyes (19.7 %) required a subsequent procedure within the first week of the primary PR of which 13.5 % (24/178) required additional laser retinopexy; 2.2 % (4/178) required another gas bubble; 1.1 % (2/178)

required additional cryotherapy; 1.1 % (2/178) required laser and cryotherapy; 1.1 % (2/178) required cryotherapy and rebubbling; and 0.6 % (1/178) required rebubbling with cryotherapy and laser retinopexy. Forty-seven eyes (26.4 %) required subsequent surgery for failed primary PR of which 38 required one surgery, 7 required two surgeries and 2 required 3 surgeries to repair the original retinal detachment. Seventeen (9.5 %) original breaks reopened, and there were 37 eyes (20.7 %) that either developed a new break or had a missed retinal break. In the phakic and pseudophakic groups, 19.2 % (24/125) and 24.5 % (13/53) had either a new or missed retinal breaks, respectively (p = 0.43). Rates of postoperative PVR occurred in 3.9 % (7/178) for the entire cohort and occurred 2.9 % (3/103) in the TPR and 5.3 % (4/71) in the NTPR, which was not significantly different between the two subgroups (p = 0.41). Other postoperative complications including cataract occurred in 28.7% (51/127); increased intraocular pressure (IOP) occurred in 7.9 % (14/178); macular pucker occurred in 26.4 % (47/178); and vitreous hemorrhage occurred in 11.8 % (21/178). Comparing the two subgroups, postoperative cataract occurred in 22.3 % (23/103) of the TPR and in 37.3% (28/75) of the NTPR, which was significantly different (p = 0.03). Postoperative increased IOP occurred in 6.8 % (7/103) of the TPR and in 9.3 % (7/75) of the NTPR, which was not significantly different (p = 0.54). Postoperative macular pucker occurred in 19.4 % (20/103) of the TPR and in 36.0% (27/75) of the NTPR, which was significantly different (p = 0.013). Lastly, postoperative vitreous hemorrhage occurred in 5.8 % (6/103) of the TPR and in 20.0% (15/75) of the NTPR, which was significantly different (p = 0.003).

The average number of subsequent surgeries required to achieve anatomic reattachment, post primary PR was similar among TPR and NTPR groups (1.2 (range 1–3) and 1.3 (range 1–3), respectively, p = 0.38). Average time to final operative intervention after initial PR in the setting of failure was 93.3 (std ±151.1, range 2–850) days for the whole cohort and 75.2 (std ±111.7, range 2–395) days for the NTPR and 106.5 (std ±174.6, range 7–850) days for the TPR (p = 0.39).

Successful primary anatomic outcome did not differ between TPR and NTPR groups at POY1 (72.8 % (75/103) vs. 74.6 % (56/75), p = 0.78). In terms of lens status, pre-PR pseudophakic eyes had worse primary anatomic outcomes at POY1 (anatomic success rates: 58 %, 31/53) compared to phakic (80 %, 100/125, p = 0.002). Factors affecting successful POY1 anatomic outcomes in univariate regression analysis (Tables 4a and 4b) were included in a stepwise multivariate regression analysis (Table 5). When controlling for confounding variables, eyes with pre-operative pseudophakia (−0.15 p = 0.03), pre-operative RD involving the inferior quadrant (−0.27, p < 0.001) and postoperative proliferative vitreoretinopathy (PVR) (−0.68, p <0.001) were associated with a significantly lower chance of achieving anatomic success at POY1 (Table 5).

Visual Outcomes

When examining the entire cohort, POY1 BCVA was maintained or improved over baseline in 80.9 % (127/157) eyes. POY1 BCVA was maintained or improved in 85.9 % (79/92) TPR eyes, and in 73.8 % (48/65) NTPR eyes. Specifically, mean POY1 BCVA was logMAR 0.28 ±0.32, (range 0–2.2, Snellen equivalent 20/38, N = 157), which was significantly improved

over baseline BCVA of logMAR 0.60 ±0.63 (range 0–2.2, Snellen equivalent 20/80; N = 178, p = 0.001). BCVA at POY2 (logMAR 0.24 ±0.33, range 0–2.2, Snellen equivalent 20/35; N = 129) and at POY3 (logMAR 0.27 ±0.37, range 0–2.2, Snellen equivalent 20/37; N = 96) remained significantly improved compared to baseline (p = 0.001 and p = 0.001, respectively). Both TPR and NTPR cohorts showed similar improvements in POY3 BCVA over baseline (TPR: logMAR 0.26 ±0.36, range 0–2.2, Snellen equivalent 20/36, N = 49, p = 0.001; NTPR: logMAR 0.29 ±0.38, range 0–2.2, Snellen equivalent 20/39, N = 47, p = 0.008).

When controlling for confounding variables, multivariate regression analysis (Table 6) showed that macula-off detachment (−0.44 logMAR, p < 0.001) and extent of RD in clock hours (−0.084 logMAR, p < 0.001) were associated with improved BCVA at 1 year. Preoperative pseudophakia (0.26 logMAR, p= 0.002), inferior retinal tears at presentation (0.62 logMAR, p = 0.009), and postoperative raised IOP (0.32 logMAR, p = 0.024) were associated with worsening POY1 BCVA. Final anatomic success was significantly associated (−1.82 logMAR, p < 0.001) with an improvement in POY3 BCVA. When controlling for confounding variables (including final anatomic success), presence of macula-off RRD (−0.52 logMAR, p < 0.001) and greater total clock hours of RRD (−0.11 logMAR/clock hour, p = 0.001) were still significantly associated with an improvement in logMAR BCVA. When controlling for confounding variables (including the three above-mentioned variables), preoperative pseudophakia was still significantly associated with a worsening (+0.31 logMAR, p = 0.005) in POY3 BCVA.

Cost Analysis

The average initial PR costs for the cohort over the entire follow-up period was $921.98 (std ±$188.61; N = 178) and for the TPR and NTPR, was $913.25±$186.91 (N=40) and $933.96±$191.53 (N=29), respectively. There was no statistically significant difference between the overall initial average PR costs (p=0.39, Figure 1, 1st set of bar graphs). The total average cost for all surgeries including subsequent procedures related to the original PR including additional laser retinopexy, cryoretinopexy or rebubbling for the entire cohort, TPR and NTPR groups was $1342.56±$912.31, $1248.37±$882.11 and $1471.91±$942.84, respectively (p = 0.10) (Figure 1, 2nd set of bar graphs). “Second surgeries” or those involving subsequent surgical procedures within the first year related to failed initial PR, included those with CPT code 67107 (scleral buckle), CPT code 67108 (vitrectomy with and without scleral buckle) and CPT code 67113 (Complex RD repair). These “second surgery” costs amounted to an average of $1893.23±$856.10 in the TPR group, an average of $1874.93±$910.57 in the NTPR group, and an average of $1883.80±$870.75 for the entire cohort. There was no significant difference in the cost of “second surgery” across the groups (p = 0.95, Figure 1, 3rd set of bar graphs).

A surgical reoperation rate of 26.5 % for the entire cohort, 27.2 % for the TPR and 25.4 % for the NTPR were based on reoperation rates obtained within our study, and assumed reoperation rates for primary scleral buckle (15.9 %; CPT code 67107) and primary vitrectomy with or without scleral buckle (11.0 %; CPT code 67108) were provided from data by Adelman et al.[34] Assuming vitrectomy (CPT code 67108) as the main method for

secondary interventions for failed primary surgeries, primary PRs amounted to an average potential total surgical cost, with reoperations based on the surgical reoperation rates for this cohort, of $2274.69 for the entire cohort, $2311.24 for traditional and $2217.25 for non-traditional cases. Estimated primary scleral buckle total surgical cost, with reoperations, was $5983.10, and primary vitrectomy with or without scleral buckle, with reoperations, was $5796.83 based on costs from a local outpatient ambulatory surgical center, EyeMD, Oakland, CA USA and assuming the rates of reoperation reported by Adelman et al.,[34] primary PR for RD was potentially 62.0 % and 60.8 % less expensive than primary scleral buckle and primary vitrectomy, respectively. In TPR, potential cost savings was 61.4 % and 60.1 % compared to primary scleral buckle and primary vitrectomy, respectively; and in NTPR, potential cost savings was 62.9 % and 61.8 % compared to primary scleral buckle and primary vitrectomy, respectively. Results were similar when assuming repair of complex retinal detachment, with vitrectomy and membrane peeling (CPT code 67113), as the preferred method of secondary intervention. In NTPR cases, average potential total surgical costs, with reoperations, totaled $2253.25; and TPR cases, with reoperations, averaged $2349.80. Estimated primary scleral buckle total surgical costs, with reoperations using repair of complex retinal detachment (CPT code 67113) were $6005.65, and primary vitrectomy with or without scleral buckle, with reoperations using CPT code 67113 were $5812.42. Potential cost savings in this NTPR cohort were still 62.5% and 61.2% compared to primary scleral buckle and primary vitrectomy, respectively. In the TPR cohort, potential cost savings remained 60.9% compared to primary scleral buckle, and 59.6% when compared to primary vitrectomy (Table 7).

Discussion

Pneumatic retinopexy has previously been shown to be a viable alternative for primary repair of RD.[1–3] Unlike its operating-room alternatives, scleral buckle and pars plana vitrectomy, PR may be performed in the clinic, obviating the need for care in a surgical center or hospital. Although originally indicated for uncomplicated RDs (with retinal breaks in the superior 8 clock hours or multiple superior breaks confined to a single clock-hour of the retina and sufficiently clear media),[1–3] having preoperative characteristics contrary to these parameters does not necessarily preclude the use of pneumatic retinopexy.[25,28,29] Previously published studies have shown a wide variation of PR primary single operation success rates, ranging between 43.75 % and 93.55 %, and also report a 90 %+ final reattachment rate, which includes subsequent surgeries.[27] In this current study of 178 eyes (156 patients) managed by a single retinal surgeon (DAB), PR resulted in successful long-term anatomic and visual outcomes at 3 years for both traditional and non-traditional criteria, with an overall success rate of 73.5 % (131/178) at 1 year. Final anatomic success including subsequent surgeries for failed primary PR at last follow-up was 98.9 % (176/178) eyes over an average of 4.8 years (range 1–10 years) of follow-up. It is important to note, however, that 78 patients treated with PR were lost to follow up prior to 1 year and this may affect the overall success rate. Seven were lost to follow up prior to SF6 gas resorption within the first month, but the remaining 71 were followed for 1 to 11 months (mean +/− std 4.9 +/− 3.0 months).

A previously published single-center study of 141 eyes who underwent PR by 7 different surgeons and accompanying fellows found no significant difference at 6 months in both anatomic outcomes and BCVA in their definition of traditional versus non-traditional PR (84.1 % vs. 74.4 %, p = 0.16). Although also a single-center, retrospective study, Goldman et al. included 7 different surgeons, which often included the assistance of fellows-in-training from the same institution, which is another source of variability. These authors also included multiple variables such as vitreous hemorrhage, bridging vessels, > 1 break separated by > 1 clock-hour, breaks in detached and attached retina, visible traction on retinal tears, extensive lattice, inferior retinal breaks, no breaks identified, Grade B or worse proliferative vitreoretinopathy and giant retinal tears.[29] These “nontraditional cases” included various pathologies (the number of cases varied from one giant retinal tear to 36 vitreous hemorrhages), and each of these could have variable effects on the final outcomes. Due to inclusion of these multiple variables in their definition of NTPR, expanding the criteria for PR remained difficult because of the possible interactions of these pre-operative characteristics affecting the final visual and anatomical outcomes. Our study utilized 3 specific variables, including multiple tears separated by > 1 clock hour apart; tears in flat or detached retina below the horizontal meridians defined at 8 and 4 o’clock; and/or mild to moderate vitreous hemorrhage. Our results confirm the findings as seen in the Goldman et al. study,[29] although with a longer follow-up of at least 1 year, and a smaller difference in success between both TPR and NTPR cohorts (72.8 % (75/103) vs. 74.6 % (56/75), p = 0.78). The smaller difference in success rates may be due to the fact that all of the PRs were performed by a single, experienced surgeon and this reduced the overall learning curve and variation in technique that would be present with multiple surgeons and fellows being involved. The PR technique was uniform with all patients receiving SF6 gas, and although eyes may have received multiple treatment modalities including cryoretinopexy, laser retinopexy or both, these eyes were all treated based on the discretion of a single surgeon in order to optimize the repair of the primary RD.

In comparing the TPR and NTPR cohorts, although the success rates were similar, postoperative cataract occurred in 37.3% (28/75) of the NTPR and in 22.3 % (23/103) of the TPR, which was significantly different (p = 0.03). Interestingly, the mean amount of SF6 gas injected in the NTPR was slightly higher compared to the TPR (0.61 vs. 0.59, p = 0.14), which could have affected cataract progression. In addition, postoperative macular pucker occurred more commonly in NTPR (36.0% (27/75)) compared to TPR (19.4 % (20/103), p = 0.013), and postoperative vitreous hemorrhage occurred more commonly in NTPR (20.0% (15/75)) compared to TPR (5.8 % (6/103), p = 0.003). These postoperative findings are not surprising, given the constellation of preoperative factors used to define NTPR, including the presence of vitreous hemorrhage and greater number of retinal breaks found in both attached and detached retina (which included breaks involving bridging vessels). The presence of vitreous hemorrhage and retinal detachment have been associated with secondary epiretinal membranes,[35] and would therefore arise more commonly in the setting of NTPR.

Using multivariate regression analysis to predict anatomic success, our study found that eyes with preoperative pseudophakia had a 15% lower chance of achieving POY1 anatomic success than phakic eyes (p = 0.03). Other significant factors affecting successful anatomic outcomes included RD involving the inferior retina and postoperative PVR. Proliferative

vitreoretinopathy had the largest effect on anatomical success (−0.68, $p < 0.001$). PVR has been previously noted to occur in 5.2% of cases in a large systemic review by Chan and colleagues.[27] In the current series, postoperative PVR occurred in only 3.9 % for the entire cohort, 2.9 % in the TPR cohort and 5.3 % in the NTPR group, but was not significantly different between the two subgroups ($p = 0.41$).

When controlling for confounding factors, eyes with preoperative pseudophakia were also associated with worse BCVA versus baseline, when compared to phakic eyes (POY1: +0.26 logMAR, $p = 0.002$; POY 3: +0.308 logMAR, $p = 0.005$). There is conflicting evidence from prior studies regarding whether pseudophakia affects success rates for PR in primary RD, but the overall consensus is that PR has higher success rates in phakic RDs compared to pseudophakic or aphakic RDs.[27, 29] Our study similarly shows that preoperative pseudophakia is significantly associated with poorer long-term anatomic and visual success. Pseudophakia may affect the ability of a surgeon to identify all of the breaks during a preoperative examination and breaks in pseudophakic eyes have been noted to be anterior to the equator, closer to the vitreous base and have a greater likelihood of having multiple breaks.[36] Not only is pseudophakia a risk factor for failure in PR, Adelman and colleagues in the European Vitreo-Retinal Society Retinal Detachment Study Report 1 demonstrated with multivariate analysis that pseudophakia was independently linked to the rate of failure (coeff. 0.38, $p=0.001$) for repair of primary retinal detachment with pars plana vitrectomy with and without scleral buckle. Even in the current study with a single experienced surgeon, 47 eyes required subsequent surgery for failed primary PR and 37 of these eyes either developed a new break or had a missed retinal break. Analyzing the lens status, on average, a greater proportion of pre-PR pseudophakic eyes had either a missed or new break, 24.5 %, compared to those who were not preoperatively pseudophakic (19.2 %), although this difference was not statistically significant ($p = 0.39$).

BCVA was maintained or improved in 80.9 % (127/157) eyes at POY1. Specifically, POY1 BCVA was maintained or improved in 85.9 % (79/92) in the traditional PR cohort vs. 73.8 % (48/65) in the NTPR cohort. Average BCVA significantly improved from baseline logMAR 0.60 (Snellen equivalent 20/80) to logMAR 0.28 (Snellen equivalent 20/38) at POY1, and both TPR and NTPR cohorts maintained similar improvements in BCVA at POY3. Not surprisingly, other factors associated with greater improvement in POY1 BCVA over baseline included macula-off detachment and extent of RD in clock hours. Preoperative pseudophakia and inferior retinal tears in the RD at presentation were associated with worsening BCVA. As mentioned previously, pseudophakia may limit the surgeon's ability to identify all the breaks and an inferior retinal tear may be difficult to adequately treat with PR due to limitations in patient positioning. Final anatomic success after PR, extent of RD in clock-hours and having a macula-off detachment at time of pneumatic retinopexy were associated with improved POY3 BCVA over baseline. Tornambe and colleagues' multicenter PR trial demonstrated that patients with macula-off RD continued to have improvement in vision after two years and 90 % of eyes achieved BCVA of 20/50 or better.[2] Our results emphasize that both macula-on and macula-off RDs have improvement with BCVA with PR but the ceiling effect with measuring BCVA change in the macula-on group may prevent this group from demonstrating a significant difference although the improvement is clearly seen in the macula-off RD group.

When compared to operation room procedures such as scleral buckle or vitrectomy with or without scleral buckle, PR remains a financially sensible decision. Tornambe demonstrated that the average total cost of PR and subsequent reoperations was 59 % compared to a scleral buckle procedure and subsequent reoperations.[37] Goldman and colleagues analyzed the cost savings for PR, and assuming an arbitrary average reoperation rate of 10 % for both primary scleral buckle and vitrectomy, estimated that PR would have cost savings of 37.9 % over scleral buckle and 48.6 % over vitrectomy.[29] Our study further elaborated on their findings using accurate values obtained from CMS for the Oakland, CA MAC Locality and a local outpatient ambulatory surgical center, EyeMD, Oakland CA. Utilizing the EVRS Retinal Detachment Study Report and their suggested scleral buckle primary failure reoperation rate of 15.9 % and vitrectomy with or without scleral buckle reoperation rate of 11.0 % and assumed subsequent reoperations for failed initial PRs to be performed with vitrectomy with or without scleral buckle (CPT code 67108), our study showed that PR had an average potential cost savings of 62 % when compared to scleral buckle and 60.8 % when compared to vitrectomy. Non-traditional and traditional PR also had an average potential cost savings of 62.9 % and 61.4 % when compared to primary scleral buckle, respectively, and 61.8 % and 60.1 % when compared to primary vitrectomy, respectively. Similarly, when adjusting the analysis to assume reoperations using repair of complex retinal detachment (CPT code 67113), average potential cost savings for the NTPR cohort were 62.5% and 61.2%, when compared to primary scleral buckle and vitrectomy, respectively. Average cost savings for the TPR cohort were 60.9% when compared to primary scleral buckle, and 59.6% when compared to primary vitrectomy. Cost savings for both pneumatic retinopexy cohorts remain at similar levels even when reoperations were adjusted to utilize CPT code 67113, instead of CPT code 67108. Previous cost analyses have shown the cost-effectiveness of PR in comparison to scleral buckling and vitrectomy,[27, 29, 37] and these studies in addition to our cost savings analysis based on specific values from our cohort emphasize the cost-effectiveness of PR for both traditional and non-traditional primary RD cases compared to intraoperative surgical procedures.

In addition, we analyzed the financial differences in TPR and NTPR. Our comparison shows that there is no statistically significant difference in total average cost for all surgeries performed between the traditional and nontraditional cohorts ($1248.37, std ±$882.11 vs. $1471.91, std ±$942.84, p = 0.10), respectively (Figure 1). Both cohorts had a similar number of subsequent surgeries to repair the primary RD if initial PR failed (TPR 1.2 (range 1–3) vs. NTPR 1.3 (range 1–3), p = 0.38). Of these subsequent surgeries, both cohorts showed similar average total costs with respect to additional scleral buckling, and vitrectomies with and without scleral buckling (TPR $1893.23, std ±$856.10 vs. NTPR $1874.93, std ±$910.57, p = 0.95). Typically, non-traditional cases would not have PR attempted as a primary treatment, but not only do our results show the overall anatomic and visual success of PR in these cases, NTPR may also substantially lower the costs of healthcare (Table 7) as it can be performed in-office, offering convenience, flexibility and expedience for the surgeon especially when compared to its surgical alternatives, which require operating room availability and associated medical staff. These findings support the possibility that PR can be performed on a wider scope of patients, regardless of payee status.

Limitations to this study include its retrospective nature, relatively limited sample size, and third-party source of surgical cost values. Seventy-eight patients were excluded from this study due to follow up of less than 1 year. By year 2 after initial PR, 49 patients had not completed follow-up. By year 3 after initial PR, there were 82 patients lost to follow-up. Patients lost to follow-up introduce the possibility of a selection bias, inevitably inherent with all retrospective studies, which may affect final outcomes in anatomic success and improvements in BCVA, although we did have patients complete on average 57.5 months of follow-up (range 12–307 months). In addition, our study used a limited sample size of 178 primary RD eyes, though this is offset by having a single surgeon perform all reported surgical procedures analyzed in this study, thereby minimizing potential variance in surgical techniques, learning curve or preoperative examinations. Lastly, our cost analysis utilized the most recent available reports from a single outpatient center in Oakland, CA, and the total costs of all surgeries were calculated based on our MAC locality and the CMS Physician Fee Schedule at the time when surgery was performed. This third-party payer perspective made several assumptions including surgical reoperation rates based on the EVRS Retinal Detachment Study Report, and given the single center, may be difficult to extrapolate to other locations. Nevertheless, this analysis utilized the most accurate CPT codes and substitutions for outdated billing codes. Our cost comparison results were based on a conservative approach, and so actual cost savings between RD repair procedures may be larger than suggested by this study. Moreover, our cost analysis may not be completely generalizable to all surgeons, who, unlike DAB, do not attempt PR on every RD (in the absence of GRT and proliferative vitreoretinopathy). It is also important to note that this is a cost-comparison study, and not a cost-utility or quality-adjusted of life year (QALY) analysis, which would require life expectancy. Even with these limitations, our study still provides the largest single-surgeon comparison between PR for traditional and non-traditional cases and its surgical alternatives for primary RD repair.

In summary, our long-term follow-up comparing traditional and nontraditional PR selected for primary repair of RD indicates that both cohorts show similar high rates of final anatomic success and long-term improvement in BCVA. Furthermore, both groups showed no statistically significant difference in costs or required number of subsequent surgeries. Expanding the use of PR to non-traditional cases may be a viable option and allow for overall healthcare cost savings compared to primary scleral buckle or vitrectomy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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d) Approval was obtained from the Western Institutional Review Board (Olympia, WA, USA) for this Health Insurance Portability and Accountability Act-compliant, retrospective interventional case series and cost comparison study, and all research adhered to the tenets of the Declaration of Helsinki. IRB was completed prospectively and approved the research design.

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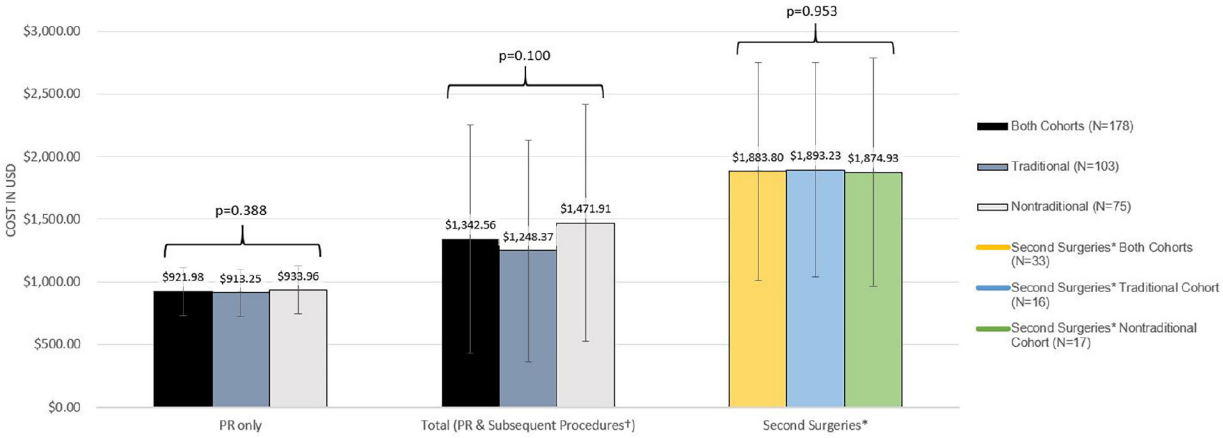

Figure 1.

Average cost of pneumatic retinopexy, second surgeries and total surgeries within postoperative year 1.

N = Number; PR = Pneumatic retinopexy; USD = United States Dollars

† Subsequent procedures indicate non-facility procedures performed related to initial PR such as laser retinopexy (67145) and cryotherapy (67141).

* Second surgeries indicates subsequent surgeries within the 1st year including CPT codes 67107 (Scleral Buckle), 67108 (Vitrectomy), and 67113 (Complex Repair).

Error bars indicate standard deviation.

Statistical significant (set at $P<0.05$).

Table 1.

Demographic Features

Demographic Features	Entire Cohort N (%)	Traditional N (%)	Non-Traditional N (%)	p-value[a]
Number of eyes	178	103	75	0.78
Success	131 (73.5)	75 (72.8)	56 (74.6)	
Failure	47 (26.5)	28 (27.2)	19 (25.4)	
Gender				
Male	127 (71.3)	67 (65.0)	60 (80.0)	**0.03**
Female	51 (28.7)	36 (35.0)	15 (20.0)	
Eye				
Right	98 (55.1)	64 (62.1)	34 (45.3)	**0.03**
Left	80 (44.9)	39 (37.9)	41 (54.7)	
Mean age (Y)	55.9	56.4	55.3	0.61
Range	14–87	20–87	14–80	
Mean follow-up (M)	57.5	59.3	55.1	0.53
Range	12–307	12–307	12–168	
Mean Duration of symptoms[b] (D)	10.1	9.3	11.1	0.57
Range	1–180	1–90	1–180	
Recent Ocular Trauma	12 (6.7)	9 (8.7)	3 (4.0)	0.20

D = days; M = months; N = number; Y = years

[a]p-value = two tailed t-test comparing traditional vs. non-traditional pneumatic retinopexy characteristics

[b]Duration of symptoms unknown in 10 eyes.

Bold font = statistical significance (set at $P < 0.05$).

Table 2.

Preoperative and Treatment Characteristics

Presence of Various Preoperative Characteristics	Entire Cohort N (%)	Traditional N (%)	Non-Traditional N (%)	p-value[a]
Macula Status	178	103	75	
Attached	106 (59.6)	59 (57.3)	47 (62.6)	0.47
Detached	72 (40.4)	44 (42.7)	28 (37.4)	
Lens Status				
Phakic	125 (70.2)	68 (66.0)	57 (76.0)	0.15
Pseudophakic	52 (29.2)	35 (34.0)	17 (22.7)	
Aphakic	1 (0.6)	0 (0.0)	1 (1.3)	
Mean no. of retinal breaks identified	2.5	1.6	3.9	< **0.001**
Range	1–13	1–5	1–13	
Mean no. of retinal breaks in detached retina	2.1	1.5	2.8	< **0.001**
Range	1–8	1–5	1–8	
Mean no. of retinal breaks in attached retina	0.5	0	1.1	< **0.001**
Range	0–6		0–6	
Mean no. of clock-hours of detached retina	4.0	4.2	3.7	0.47
Range	1–12	1–12	1–12	**0.01**
Presence of lattice degeneration	49 (27.5)	21 (20.3)	28 (37.3)	
Average amount of SF6 gas injected	0.60	0.59	0.61	0.14
Range	0.40–0.80	0.42–0.74	0.40–0.80	
Initial treatment modalities				
Cryotherapy	117 (65.7)	83 (80.6)	34 (45.3)	< **0.001**
Laser Retinopexy	16 (9.0)	6 (5.8)	10 (13.3)	0.08
Combination	45 (25.2)	14 (13.6)	31 (41.3)	< **0.001**
Reopening of original break	17 (9.5)	11 (10.7)	6 (8.0)	0.55
New or missed retinal breaks	37 (20.8)	22 (21.4)	15 (20.0)	0.83
Additional treatment within 1 week	35 (19.7)	20 (19.4)	15 (20.0)	0.92
Rebubble Only	4 (2.2)	3 (2.9)	1 (1.3)	
Cryotherapy Only	2(1.1)	1 (1.0)	1 (1.3)	

Presence of Various Preoperative Characteristics	Entire Cohort N (%)	Traditional N (%)	Non-Traditional N (%)	p-value[a]
Laser Retinopexy Only	24 (13.5)	13 (12.6)	11 (14.7)	
Laser and Cryotherapy	2(1.1)	1 (1.0)	1 (1.3)	
Rebubble and Cryotherapy	2(1.1)	1 (1.0)	1 (1.3)	
Rebubble, Cryotherapy and Laser	1 (0.6)	1 (1.0)	0 (0.0)	
Eyes requiring additional procedures[b]	47 (26.4)	28 (27.2)	19 (25.3)	0.89
1	38	24	14	
2	7	3	4	
3	2	1	1	
Mean time to final definitive intervention (D)	93.3	106.6	75.2	0.39
Range	2–850	7–850	2–395	

D = days; N = number; no. = number; SF6 = sulfur hexafluoride

[a] p-value = two tailed t-test comparing traditional vs. non-traditional pneumatic retinopexy characteristics

[b] Additional procedures include scleral buckle, vitrectomy, or combined scleral buckle/vitrectomy

Bold font = statistical significance (set at $P < 0.05$).

Table 3.

Non-Traditional Preoperative Characteristics

Presence of Various Non-Traditional Preoperative Characteristics	N (%)
Multiple tears in the RD > 1 clock hour apart	25 (33.3%)
Vitreous Hemorrhage	18 (24.0%)
Multiples tears in the RD > 1 clock hour apart and tears in flat retina below 8 and 4 o'clock	13 (17.3%)
Tears in flat retina below 8 and 4 o'clock	9 (12.0%)
Vitreous Hemorrhage, Multiple Tears in the RD > 1 clock hour apart and Tears in flat retina	4 (5.3%)
Tears in the RD below 8 and 4 o'clock	3 (4.0%)
Vitreous Hemorrhage and Multiple tears in the RD > 1 clock hour apart	1 (1.3%)
Vitreous Hemorrhage and Tears in flat retina below 8 and 4 o'clock	1 (1.3%)
Multiple Tears in the RD > 1 clock hour apart, Tears in the RD below 8 and 4 o'clock and Tears in flat retina below 8 and 4 o'clock	1 (1.3%)

N = number; RD = Primary Retinal Detachment

Table 4a.

Univariate Analysis Demonstrating Association between Pre-operative Characteristics and either Anatomic or Visual Outcome

Clinical Factors	Association with POY1 Anatomic Success[a], *P*	Association with POY1 BCVA, *P*	Association with POY3 BCVA, *P*
Eye laterality (left)	0.703	0.944	0.996
Older age	0.688	0.209	0.865
Gender (female)	0.862	0.255	0.429
Cataract (unclear natural lens present)	0.418	0.716	0.229
Status post lensectomy	**0.003**	**0.022**	**0.012**
PCIOL	**0.001**	**0.005**	**0.007**
ACIOL	0.949	0.068	0.291
Aphakia	0.551	0.257	0.281
History of ocular trauma	0.418	0.380	0.349
Duration of symptoms prior to PR	0.548	0.269	0.657
Presence of macular-off RRD at time of PR	0.300	< **0.001**	< **0.001**
Extent of RD (total clock hours)	0.130	< **0.001**	< **0.001**
Presence of RD in superior quadrant	0.243	0.069	**0.010**
Presence of RD in nasal quadrant	0.187	**0.017**	0.866
Presence of RD in inferior quadrant	< **0.001**	0.222	0.499
Presence of RD in temporal quadrant	0.078	0.440	0.153
Extent of RD (total # of quadrants involved)	**0.048**	< 0.001	0.011
Extent of RD (< 3 clock hours spanned)	0.584	**0.001**	0.008
Extent of RD (3–6 clock hours spanned)	0.494	0.310	0.085
Extent of RD (> 6 clock hours spanned)	0.069	**0.002**	0.261
Presence of RRD in inferior 6 clock hours	0.189	**0.004**	0.202
Total # of retinal tears within eye at time of PR	0.329	0.072	0.972
Total # of retinal tears within RD at time of PR	0.287	0.103	0.929
Multiple retinal tears within RD at time of PR	0.920	0.166	0.922

Clinical Factors	Association with POY1 Anatomic Success[a], *P*	Association with POY1 BCVA, *P*	Association with POY3 BCVA, *P*
Inferior retinal tears in RD at time of PR	0.282	0.027	0.280
Total # retinal tears within flat retina at time of PR	0.657	**0.257**	0.961
Retinal tears ≥ ½ clock hour in size at time of PR	0.099	0.614	0.718
Retinal tears located in superior quadrant	0.679	0.278	0.061
Retinal tears located in nasal quadrant	0.571	0.768	0.119
Retinal tears located in inferior quadrant	0.952	0.646	0.491
Retinal tears located in temporal quadrant	0.399	0.245	0.583
Number of quadrants containing retinal tears	0.887	0.639	0.860
Lattice degeneration present at time of PR	0.463	0.814	0.829
Vitreous hemorrhage present at time of PR	0.770	0.541	0.446
Milliliters of SF_6 gas used	**0.033**	0.412	0.528
Cryotherapy used at time of PR	**0.021**	0.626	0.339
Laser used at time of PR	0.704	0.598	0.924
Cryotherapy and laser used at time of PR	0.664	0.990	0.875
Presence of “complicated RRD”[b]	0.716	0.745	0.653

ACIOL = anterior chamber intraocular lens ; BCVA = Best Corrected Visual Acuity; PCIOL = posterior chamber intraocular lens; POY = postoperative year; PR = pneumatic retinopexy; RD = rhegmatogenous retinal detachment; SF6 = sulfur hexafluoride; # = number

Bold font = statistical significance (set at $P < 0.05$).

[a]Anatomic success is defined as an attached retina and not requiring adjuvant surgical intervention for RD in the same eye (scleral buckle, vitrectomy, a combination of the two, or additional PR) within 1 year after initial PR.

[b]“Complicated RRD” is defined as RRDs having multiple tears separated by ≥1 clock hour apart; tears in flat or detached retina below the horizontal meridians defined at 8 and 4 o’clock; and/or mild to moderate vitreous hemorrhage.

Table 4b.

Univariate Analysis Demonstrating Association between Post-operative Characteristics and either Anatomic or Visual Outcome

Clinical Factors	Association with POY1 Anatomic Success[a], *P*	Association with POY1 BCVA, *P*	Association with POY3 BCVA, *P*
Reopening of original break after PR	< **0.001**	0.729	0.178
Rebubble with SF_6 gas after PR	< **0.001**	0.503	0.321
Second surgery[b] required after PR	< **0.001**	0.659	0.815
New retinal break after PR	< **0.001**	0.657	0.300
Additional cryotherapy after PR	0.006	0.130	0.107
Additional laser after PR	0.595	0.633	0.735
Presence of proliferative vitreoretinopathy after PR	< **0.001**	0.090	< **0.001**
Presence of cataract after PR	0.862	0.085	0.812
Presence of ocular hypertension after PR	**0.006**	**0.023**	**0.045**
Presence of epiretinal membrane after PR	0.589	0.457	**0.020**
Presence of vitreous hemorrhage after PR	0.004	0.124	**0.014**

BCVA = Best Corrected Visual Acuity; POY = postoperative year; PR = pneumatic retinopexy;

SF6 = sulfur hexafluoride

Bold font = statistical significance (set at $P < 0.05$).

[a]Anatomic success is defined as an attached retina and not requiring adjuvant surgical intervention for RD in the same eye (scleral buckle, vitrectomy, a combination of the two, or additional PR) within 1 year after initial PR.

[b]Second surgery required after PR indicates any subsequent surgery related to repair of primary RD besides additional gas bubble, laser retinopexy, or cryoretinopexy.

Table 5.

Multivariate Analysis Demonstrating Association Between Clinical Factors and Probability of Anatomic Success at Postoperative Year 1

Clinical Factor	Adjusted Probability[a]	95% CI	*P*
PCIOL	−0.15	−0.29 – −0.015	**0.030**
RD including inferior quadrant	−0.27	−0.41 – −0.14	< **0.001**
Postoperative PVR	−0.68	−0.99 – −0.38	< **0.001**

PCIOL = posterior chamber intraocular lens; POY = postoperative year; PR = pneumatic retinopexy; PVR = proliferative vitreoretinopathy; RD = rhegmatogenous retinal detachment

[a]The table exhibits adjusted decreased probability in percentage points of achieving anatomic success at POY1.

Bold font = statistical significance (set at $P < 0.05$).

Table 6.

Multivariate Analysis Demonstrating Association Between Clinical Factors and Probability of Best Corrected Visual Acuity Improvement at Postoperative Year 1 and 3

Clinical Factor	Adjusted Coefficient[a]	95% CI	*P*
Postoperative Year 1			
PCIOL	+0.26	+0.10 – +0.43	**0.002**
Inferior retinal tears in RD	+0.62	+0.16 – +1.08	**0.009**
Macular-off RD at time of PR	−0.44	−0.60 – −0.28	< **0.001**
Extent of RD (total clock hours)	−0.084	−0.12 – −0.05	< **0.001**
Postoperative raised IOP	+0.32	+0.04 – +0.60	**0.024**
Postoperative Year 3			
PCIOL	+0.31	+0.095 – +0.52	**0.005**
Macular-off RD at time of PR	−0.52	−0.74 – −0.30	< **0.001**
Extent of RD (total clock hours)	−0.11	−0.17 – −0.047	**0.001**
Final anatomic success	−1.82	−2.51 – −1.13	< **0.001**

IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; PCIOL = posterior chamber intraocular lens; PR = pneumatic retinopexy; RD = rhegmatogenous retinal detachment.

[a]A greater positive adjusted coefficient within the table indicates worsening postoperative logMAR best corrected visual acuity.

Bold font = statistical significance (set at $P < 0.05$).

Table 7:

Cost Comparative Analysis Between Nontraditional Pneumatic Retinopexy and Either Primary Scleral Buckle or Vitrectomy

Procedure Breakdown	Potential Average Cost Per Procedure in 2017 ($)	Reoperation Rates (%)[d]	Potential Average Total Cost with Reoperations ($)	Potential Cost Savings vs. Scleral Buckle (%)	Potential Cost Savings vs. Vitrectomy With/Without Scleral Buckle (%)
Pneumatic retinopexy[a]	**890.76**	25.4	2217.25	62.9	61.8
Surgeon fee[b]	890.76				
Scleral buckle[a]	**5152.75**	15.9	5983.10		
Surgeon fee	1152.75				
Ambulatory surgery center fee[c]	3500.00				
Anesthesia fee	500.00				
Vitrectomy[a]	**5222.37**	11.0	5796.83		
Surgeon fee	1222.37				
Ambulatory surgery center fee	3500.00				
Anesthesia fee	500.00				

CPT = Current Procedural Terminology

[a] CPT-10 codes: Pneumatic retinopexy (67110), Scleral buckle (67107), Vitrectomy with or without scleral buckle (67108).

[b] Surgeon fees for procedures were obtained as National Payment Amounts from Centers for Medicare and Medicaid Services 2017 physician fee schedules.

[c] Ambulatory surgery center fee and anesthesia fee were provided by EyeMD, an outpatient ambulatory surgical center located in Oakland, CA, USA.

[d] Reoperation rates for nontraditional pneumatic retinopexy assumed to be 25.4%, based upon surgical intervention rates in our study. Reoperation rates for scleral buckle and vitrectomy, 15.9% and 11.0% respectively, were based upon surgical intervention rates given by Adelman *et al.*[34]