Scientific Research Publishing

Open Journal of Ophthalmology, 2026, 16(4), 438-466
https://www.scirp.org/journal/ojoph
ISSN Online: 2165-7416
ISSN Print: 2165-7408

Determinants of Anatomical and Functional Success in Rhegmatogenous Retinal Detachment Repair: A Survival Analysis of Prognostic Factors and the Role of Pneumatic Retinopexy

Ali Tonuzi[1], Orjeta Tonuzi[1], Migena Beqiri[2], Luan Qafmolla[3*]

[1]Eyes Frensh Hospital, University Hospital Center "Mother Theresa", Tirana, Albania
[2]Albania Eye Center, Tirana, Albania
[3]Faculty of Natural Science, University of Tirana, Tirana, Albania
Email: *l_qafmolla@hotmail.com

How to cite this paper: Tonuzi, A., Tonuzi, O., Beqiri, M. and Qafmolla, L. (2026) Determinants of Anatomical and Functional Success in Rhegmatogenous Retinal Detachment Repair: A Survival Analysis of Prognostic Factors and the Role of Pneumatic Retinopexy. *Open Journal of Ophthalmology*, **16**, 438-466.
https://doi.org/10.4236/ojoph.2026.164036

Received: September 10, 2026
Accepted: November 13, 2026
Published: November 16, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/

Open Access

Abstract

Rhegmatogenous Retinal Detachment (RRD) is a vision-threatening ophthalmic emergency requiring prompt surgical intervention to prevent irreversible visual loss. Although Pars Plana Vitrectomy (PPV) remains the standard treatment for most cases, Pneumatic Retinopexy (PR) has reemerged as a minimally invasive alternative in carefully selected eyes. Identifying factors associated with anatomical success and visual recovery remains essential for optimizing surgical decision-making. A retrospective-prospective cohort study was conducted including 193 consecutive eyes that underwent surgical repair for primary RRD between 2022 and September 2025. Eyes were treated with either PPV or PR according to predefined clinical and anatomical criteria. Demographic data, preoperative clinical characteristics, surgical variables, and postoperative outcomes were analyzed. The primary endpoint was anatomical success, defined as the absence of retinal redetachment. Secondary outcomes included final Best Corrected Visual Acuity (BCVA), logMAR, predictors of visual recovery, and redetachment free survival. Multivariable linear and logistic regression analyses, Kaplan-Meier survival analysis, and Cox proportional hazards regression were performed. Primary anatomical success was achieved in 87.6% of eyes, while retinal redetachment occurred in 12.4% during follow-up. Mean BCVA improved significantly from 1.90 ± 0.65 logMAR preoperatively to 0.57 ± 0.61 logMAR postoperatively, corresponding to a mean improvement of 1.33 logMAR units. Multivariable linear regression identified longer symptom duration, macula-off retinal detachment, and post-

operative retinal redetachment as independent predictors of poorer final BCVA. Multivariable logistic regression showed that macula-off retinal detachment, PVR Grade C, and postoperative retinal redetachment were independently associated with lower odds of achieving functional success. PPV was associated with a higher rate of primary anatomical success and a lower rate of retinal redetachment than PR; however, these differences should be interpreted in the context of non-randomized treatment allocation and potential confounding by indication. PR achieved comparable or superior visual outcomes in carefully selected eyes despite an increased risk of recurrent retinal detachment. Cox regression analysis demonstrated a significantly higher hazard of redetachment following PR compared with PPV. Modern surgical management of RRD provides high anatomical success and substantial visual improvement. Early diagnosis and timely surgical intervention remain the most important determinants of favorable visual outcomes. Although PPV offers greater anatomical stability, PR represents an effective minimally invasive alternative for appropriately selected eyes, supporting an individualized approach to the surgical management of primary RRD.

Keywords

Rhegmatogenous Retinal Detachment, Pars Plana Vitrectomy, Pneumatic Retinopexy Visual Acuity, Proliferative Vitreoretinopathy, Retinal Redetachment, Prognostic Factors

1. Introduction

RRD is one of the most vision-threatening ophthalmic emergencies, requiring prompt diagnosis and timely surgical intervention to prevent irreversible visual loss. Advances in vitreoretinal surgery have substantially improved both anatomical reattachment rates and functional outcomes; however, postoperative prognosis continues to depend on multiple patient-, disease-, and treatment-related factors. Surgical management has evolved considerably over recent decades, with PPV becoming the standard approach for most complex retinal detachments, while PR remains a valuable minimally invasive alternative in carefully selected cases. A comprehensive understanding of the indications, surgical techniques, and prognostic determinants associated with these procedures provides the clinical framework for interpreting the findings of the present study.

1.1. Pars Plana Vitrectomy in the Management of Rhegmatogenous Retinal Detachment

Over the past decades, PPV has become the standard first-line surgical treatment for RRD, and is now the most commonly performed procedure for its repair. The procedure aims to eliminate vitreoretinal traction, a key pathogenic mechanism underlying retinal breaks and subsequent retinal detachment. Removal of the vitreous gel and associated membranes relieves tractional forces, facilitates retinal

reattachment, and reduces the likelihood of recurrent detachment [1].

Standard PPV involves transscleral access through the pars plana, followed by core vitrectomy, induction of posterior vitreous detachment when required, and meticulous removal of the peripheral vitreous. Adjunctive agents such as triamcinolone acetonide may be used to improve visualization of residual vitreous cortex, while perfluorocarbon liquids can assist retinal stabilization in selected complex cases. Retinal breaks are subsequently sealed using laser photocoagulation or cryopexy, and internal tamponade is achieved with expansile gases or silicone oil depending on the complexity of the detachment [2].

Technological advances, including small-gauge instrumentation, wide-angle visualization systems, and enhanced vitreous cutters, have substantially improved surgical precision and efficiency. As a result, PPV has become the preferred strategy for many complex RRD cases, with contemporary studies reporting primary anatomical success rates exceeding 85% - 90% [3].

1.2. Pneumatic Retinopexy in the Management of Rhegmatogenous Retinal Detachment

PR is a minimally invasive procedure that achieves retinal reattachment through intravitreal gas tamponade combined with retinopexy. The fundamental surgical principle involves the use of an intravitreal gas bubble, whose buoyancy and surface tension facilitate closure of retinal breaks; adherence to the prescribed postoperative head positioning allows the retinal pigment epithelium to progressively absorb subretinal fluid, thereby promoting successful retinal reattachment [4] [5].

Sulfur hexafluoride (SF_6) and perfluoro propane (C_3F_8) are the most frequently used tamponade agents because of their prolonged intraocular persistence. Successful outcomes depend largely on careful patient selection, with optimal candidates presenting superior retinal breaks, limited retinal detachment, minimal or absent proliferative vitreoretinopathy, and the ability to maintain postoperative positioning. Conversely, inferior retinal breaks, advanced PVR, and poor compliance with positioning requirements may limit the effectiveness of the procedure [5] [6].

Compared with PPV, PR offers several advantages, including lower surgical invasiveness, preservation of the crystalline lens, reduced healthcare resource utilization, and faster postoperative recovery. Although the primary anatomical success rate of pneumatic retinopexy is generally lower than that achieved with PPV, evidence from the PIVOT trial and subsequent reviews indicates that appropriately selected patients can achieve comparable final anatomical success and superior functional outcomes, including better visual acuity and lower retinal displacement. Therefore, PR remains an important therapeutic option in the contemporary management of primary RRD [6] [7].

1.3. Intraocular Tamponades

The choice of intraocular tamponade was based on retinal detachment character-

istics, macular involvement, the presence of PVR, and surgeon judgment. Silicone oil was primarily reserved for complex cases, including advanced PVR, giant retinal tears, extensive detachments, or situations requiring prolonged retinal support.

For gas tamponade, a non-expansile 12% perfluoropropane (C_3F_8) mixture was used in all cases, whereas sulfur hexafluoride (SF_6) was not utilized during the study period. The preference for C_3F_8 reflected its longer intraocular duration, providing sustained postoperative retinal tamponade. The selected concentration was consistent with established vitreoretinal practice, balancing prolonged tamponade effectiveness with a reduced risk of excessive postoperative intraocular pressure elevation [8]-[10].

1.4. Surgical Decision-Making in RRD

Despite major advances in vitreoretinal surgery, the optimal management of RRD remains individualized and depends on anatomical, clinical, and patient-related factors. Surgical selection among PPV, PR, scleral buckling (SB), or combined approaches is influenced by macular status, characteristics of retinal breaks, presence of PVR, lens status, symptom duration, and patient compliance. PPV is generally preferred for complex RRD because it enables comprehensive relief of vitreoretinal traction, treatment of retinal breaks, and use of internal tamponade agents, resulting in high anatomical success rates in contemporary practice. In contrast, PR offers a less invasive alternative for appropriately selected patients, although its success is highly dependent on retinal break configuration and adherence to postoperative positioning [3] [5] [7] [11].

The presence of advanced PVR and macular involvement is among the most important determinants of surgical strategy and prognosis. Furthermore, the choice of intraocular tamponade should be tailored to the complexity of the detachment and the anticipated duration of retinal support required [7].

Given the heterogeneity of RRD presentation and treatment options, identifying factors associated with anatomical reattachment and visual recovery remains clinically relevant. Therefore, this study aimed to evaluate anatomical and functional outcomes following surgical repair of RRD and to determine independent prognostic factors influencing postoperative success using multivariate and survival analyses [12].

2. Material and Methods

2.1. Study Design

This study was conducted as a retrospective-prospective clinical cohort study comprising two sequential components. The retrospective component included eyes that underwent surgical management for RRD between 2022 and 2024. For these eyes, baseline clinical characteristics, surgical details, and postoperative outcomes were initially obtained from existing clinical records. The prospective com-

ponent consisted of active eye re-evaluation and follow-up. Eye re-evaluation and active data collection commenced in June 2024 and continued through September 2025. Eyes that had undergone surgery during the retrospective period were contacted and invited to participate in a comprehensive ophthalmic assessment, allowing the collection of additional clinical and functional outcome data at follow-up. Eyes treated during the prospective period were evaluated and followed according to the same predefined clinical assessment protocol. Accordingly, the study incorporated both retrospective extraction of previously recorded clinical information and prospective collection of follow-up data obtained through direct patients assessment. The two components were analyzed within the same clinical cohort according to the predefined study objectives and outcome measures.

2.2. Study Population

The study population consisted of eyes with RRD, that underwent surgical treatment at the tertiary ophthalmology referral center "Albania Eye Center".

2.3. Inclusion Criteria

Clinically confirmed RRD; Surgical management with PPV or PR; Minimum postoperative follow-up of 6 months; Complete clinical and surgical documentation available.

2.4. Exclusion Criteria

Exudative or exclusively tractional retinal detachment; Severe ocular trauma associated with extensive structural damage; Ocular comorbidities with a substantial impact on visual acuity (e.g., advanced optic neuropathy); Incomplete postoperative follow-up data.

Demographic, clinical, and surgical variables potentially associated with anatomical and visual outcomes were systematically collected and analyzed as described below.

2.5. Analytic Unit and Endpoint Definitions

The analytic unit was the affected eye, ensuring independence of observations, only one eye per patient was included in the study. Accordingly, the final analytic cohort comprised 193 eyes.

Symptom duration was defined using two distinct time intervals. Time from symptom onset to clinical presentation was defined as the number of days between the first reported onset of RRD-related symptoms and the first clinical examination at the study center. Time from symptom onset to surgery was defined as the number of days between symptom onset and the date of the primary retinal detachment repair. These intervals were recorded separately and were not considered interchangeable. When time-to-surgery was used in subgroup or multivariable analyses, it referred specifically to the interval from symptom onset to the primary surgical procedure.

Primary anatomical success was assessed after the initial surgical intervention. An eye was classified as having primary anatomical success only when the retina remained attached without postoperative retinal redetachment and without the need for additional retinal reattachment surgery during the predefined follow-up period. Any postoperative retinal redetachment requiring reintervention was classified as a primary anatomical failure/event, irrespective of the anatomical result achieved after subsequent surgery. Thus, secondary or subsequent retinal reattachment procedures did not convert a primary failure into primary anatomical success.

For visual outcome analyses, final BCVA was defined as the last valid best-corrected visual acuity measurement available during the postoperative follow-up period, provided that the eye had completed at least 6 months of follow-up. The final BCVA assessment was based on the clinical status of the eye at that final follow-up visit, including eyes that had undergone additional treatment after postoperative retinal redetachment. Eyes without a valid BCVA measurement at the required follow-up assessment were excluded from analyses requiring final BCVA. For eyes, in which retained silicone oil was recorded as a postoperative status variable, its presence did not constitute an exclusion criterion for final BCVA analysis.

2.6. Clinical Variables

Clinical assessment included ocular characteristics at presentation, disease severity indicators, and relevant ocular and systemic comorbidities. Affected eye (OD/OS); Macular status (macula-on or macula-off); Time from symptom onset to clinical presentation (days); Time from symptom onset to primary surgery (days); Number and location of retinal breaks; Grade of proliferative vitreoretinopathy (PVR); Myopia; Diabetes mellitus; Arterial hypertension; Ocular trauma; Other systemic diseases.

2.7. Surgical Variables

Surgical variables comprised procedural characteristics and adjunctive intraoperative interventions were also analyzed. Surgical technique (PPV or PR); Type of intraocular tamponade; Endolaser photocoagulation or cryopexy; Internal limiting membrane (ILM) and/or epiretinal membrane (ERM) peeling; Combined phacoemulsification.

2.8. Primary and Secondary Outcomes

The primary and secondary outcome measures were predefined to evaluate both anatomical and functional surgical results.

2.9. Primary Outcome

The primary outcome was primary anatomical success after the initial retinal detachment repair. Primary anatomical success was defined as complete retinal reattachment maintained throughout the predefined follow-up period without post-

operative retinal redetachment and without the need for additional retinal reattachment surgery [13].

2.10. Secondary Outcomes

Secondary outcomes included: final best-corrected visual acuity (BCVA), expressed in logarithm of the minimum angle of resolution (logMAR) units; time to retinal redetachment and requirement for additional retinal reattachment surgery following postoperative redetachment.

For visual acuity analyses, BCVA measurements were converted to logMAR values [13] [14]. The final BCVA was defined as the last valid postoperative BCVA measurement obtained during follow-up after completion of at least 6 months of follow-up.

2.11. Postoperative Follow-Up

Eyes were followed for a minimum of 6 months and up to 4 years after the primary retinal detachment repair. Follow-up assessments included best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, dilated fundus examination, and optical coherence tomography (OCT) when clinically indicated.

The date of the primary surgical procedure was used as the time origin for postoperative follow-up and time-to-event analyses. Retinal redetachment was recorded when recurrent retinal detachment was clinically documented after the primary repair. The date of documented retinal redetachment was used as the event date for survival analyses. Eyes without documented redetachment were censored at the date of their last available follow-up assessment. Final BCVA was defined as the last valid postoperative BCVA measurement available during the follow-up period after at least 6 months of follow-up. Additional retinal surgery performed after postoperative redetachment did not alter the classification of the initial procedure as a primary anatomical failure. Final visual acuity after additional surgery remained eligible for analysis when a valid BCVA measurement was available at the final follow-up visit.

2.12. Prespecified Clinical Confounders

In our study, the choice between pars plana vitrectomy (PPV) and pneumatic retinopexy (PR) was based on clinical and anatomical characteristics rather than random allocation, therefore, potential confounding by indication was considered in the comparative analysis. Prespecified clinical variables considered potential confounders included macular status (macula-on versus macula-off), PVR grade, retinal break configuration, extent of retinal detachment, lens status, and symptom duration from onset to primary surgery. These variables were selected a priori because they may influence both the choice of surgical technique and postoperative anatomical or functional outcomes. Adjusted analyses comparing PPV and PR were interpreted as associations between surgical technique and outcomes rather than as estimates of causal treatment superiority. Because, for as much as, the

number of postoperative retinal redetachment events was limited, the recurrence analysis was re-specified using a parsimonious multivariable time-to-event approach. While, with regard to give the limited number of redetachment events, the multivariable Cox proportional hazards model was restricted to a small number of clinically relevant, prespecified covariates to minimize overfitting. As well as, the covariates were selected a priori based on clinical relevance and potential association with postoperative retinal redetachment and treatment selection, rather than solely on univariable statistical significance. Missing data were assessed before model fitting, and the final Cox analysis included eyes with complete data for the prespecified covariates.

2.13. Statistical Analysis

Data were analyzed using descriptive and inferential statistical methods. Continuous variables were reported as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages (%), based on the following statistical tests, which we have applied:

- Student's *t*-test for continuous variables;
- Chi-square test for categorical variables;
- Multivariable linear regression to identify predictors of final BCVA; multivariable logistic regression.
- Multivariable logistic regression to identify predictors of functional success;
- Kaplan-Meier survival analysis and Cox proportional hazards regression for time-to-redetachment analysis. The P-value < 0.05 was considered statistically significant.

Figure 1 presents the study flowchart and anatomical outcomes stratified by surgical technique among eyes treated in "Albanian Eye Center", at the tertiary ophthalmic referral facility.

The study flowchart illustrates the eye selection, the study inclusion process, treatment allocation, and primary anatomical outcomes [14] [15]. A total of 193 eyes met the eligibility criteria and were included in the analysis. Of these, 167 (86.5%) eyes underwent PPV and 26 (13.5%) eyes underwent PR. Primary anatomical success was achieved in 152 (91.0%) PPV-treated eyes, and 18 (69.2%) PR-treated eyes. Retinal redetachment occurred in 23 (11.9.0%) of treated eyes.

3. Results

The results of the study are presented below, focusing on the baseline clinical characteristics of the study population consisted of eyes with RRD, surgical outcomes, anatomical success, postoperative retinal redetachment, and functional visual outcomes. The analyses also examined factors associated with anatomical and functional outcomes and identified independent predictors through multivariable statistical models. All results are reported based on the corresponding statistical analyses described in the following subsections.

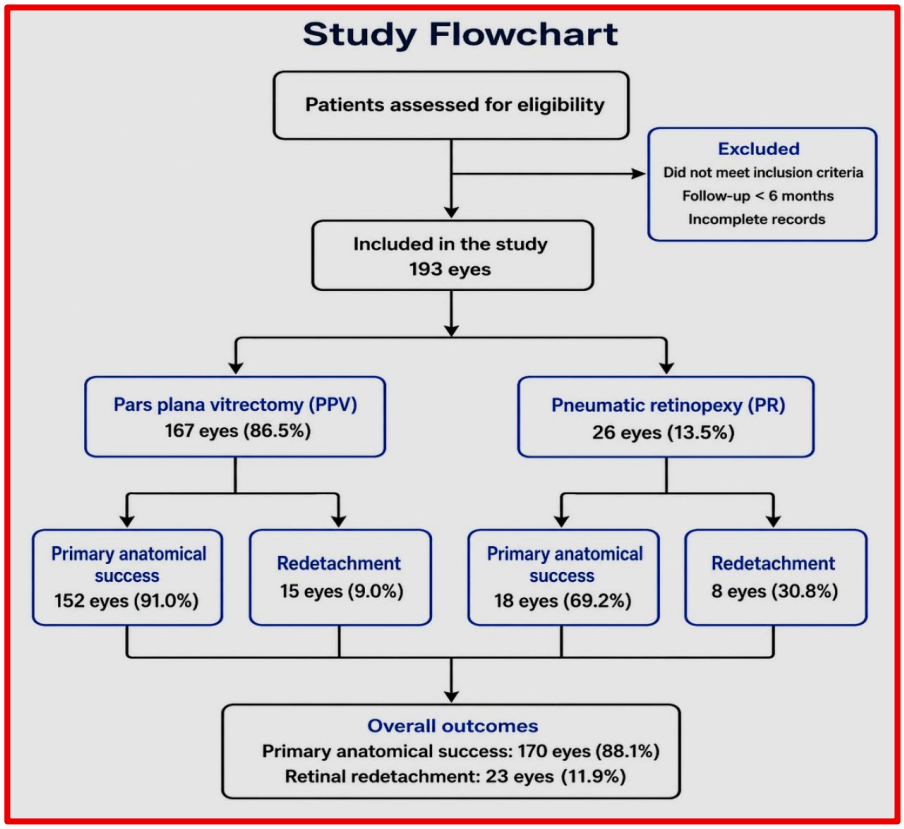


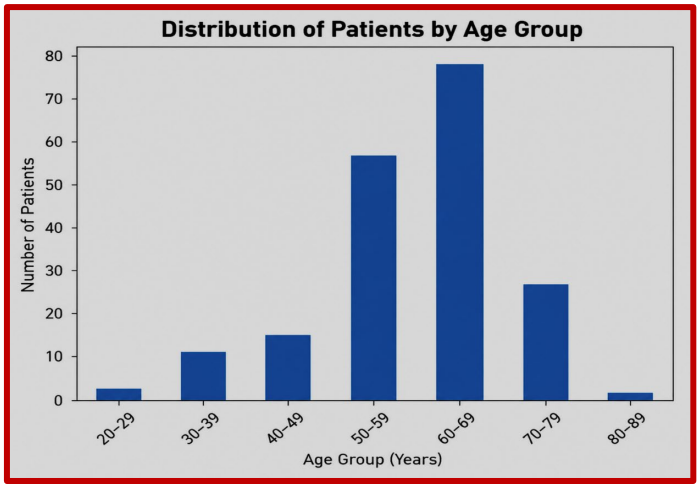
Figure 1. Study flowchart and anatomical outcomes according to surgical technique.

3.1. Demographic Characteristics of the Study Population

A total of 193 eyes diagnosed with RRD were included in the study. The mean age was 59.2 ± 11.2 years, ranging from 23 to 84 years. The highest proportion of eyes was observed in the 60 - 69-year age group, followed by those aged 50 - 59 years. Regarding sex distribution 109 (56.5%) eyes were from males, and 84 (43.5%) eyes were from female, indicating a slight male predominance. Of the 193 affected eyes, 114 (59.1%) were right eyes (OD), and 79 (40.9%) were left eyes (OS). The age distribution and eye surgical intervention are presented in Table 1, and Graph 1.

Table 1. The age distribution regarding gender and eye surgical intervention.

Variables	Values
Total eyes	193
Mean age (years)	59.2 ± 11.2
Age range (years)	23 - 84
Male sex	109 (56.5%)
Female sex	84 (43.5%)
Right eye (OD)	114 (59.1%)
Left eye (OS)	79 (40.9%)



Graph 1. Gender and eye surgical intervention according to the age distribution.

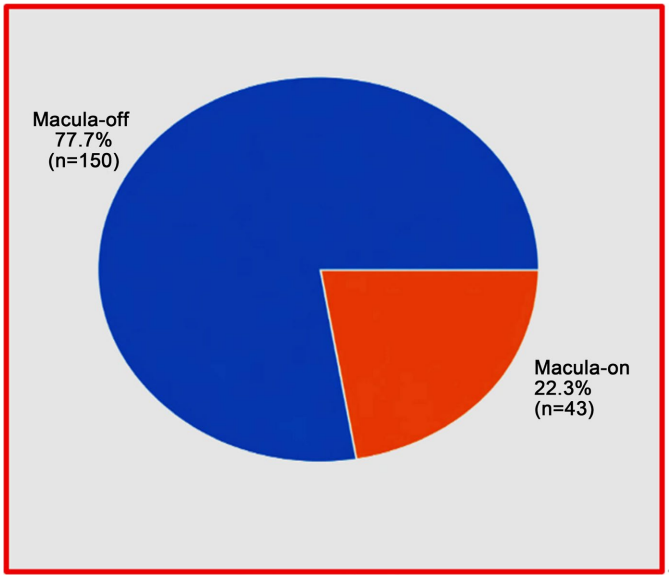
3.2. Preoperative Clinical Characteristics

Preoperative disease characteristics were assessed according to macular status, PVR grade, and the anatomical location of retinal breaks, as presented below.

3.3. Macular Status

Among the 193 eyes included in the study, 150 (77.7%) eyes presented with macula-off RRD, while 43 (22.3%) eyes presented with macula-on RRD, as shown in Graph 2.

The predominance of macula-off RRD in our cohort suggests that many eyes presented after involvement of the central retina. This finding is clinically relevant because macular detachment is generally associated with poorer visual outcomes [16].



Graph 2. Distribution of patients according to macular status.

3.4. Proliferative Vitreoretinopathy (PVR)

Among the 193 eyes included in the study, Grade B, PVR was the most frequent presentation, observed in 83 (43.0%) eyes, followed by Grade A, PVR in 65 (33.7%) eyes, and Grade C PVR in 45 (23.3%) eyes, as shown in Table 2 [17] [18].

Table 2. Distribution of PVR grades.

PVR grade	Number of eyes (n)	Percentage (%)
Grade A	65	33.7
Grade B	83	43.0
Grade C	45	23.3

3.5. Retinal Break Location

The distribution of retinal break locations is summarized in Table 3. The supertemporal quadrant was the most common site of retinal breaks, identified in 78 (40.4%) eyes, followed by the superior quadrant in 52 (26.9%) eyes. Inferotemporal breaks were observed in 28 (14.5%) eyes, whereas inferonasal and nasal breaks were identified in 19 (9.8%), and 16 (8.3%) eyes respectively.

Table 3. Distribution of retinal break locations.

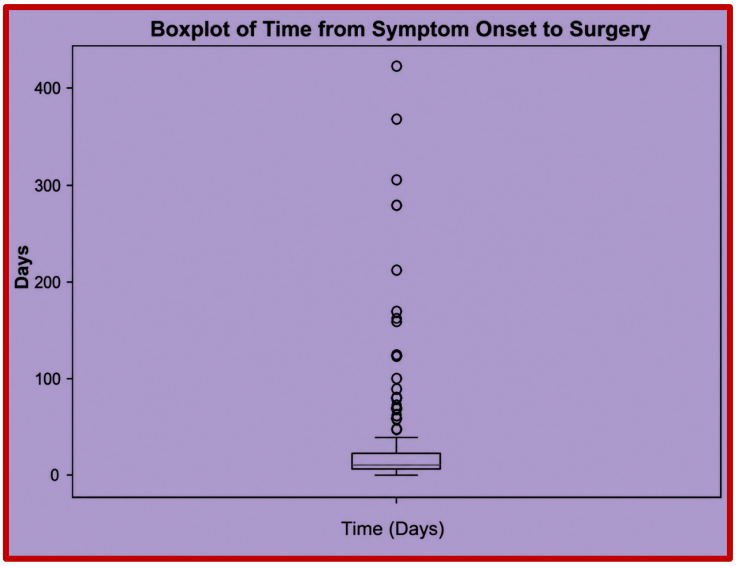
Retinal break location	Number of eyes	%
Supertemporal	78	40.4
Superior	52	26.9
Inferotemporal	28	14.5
Inferonasal	19	9.8
Nasal	16	8.3
Total	**193**	**100**

3.6. Symptom Duration before Presentation

The mean duration from symptom onset to clinical presentation was 29.8 ± 59.3 days, with a range of 1 to 420 days. The distribution of symptom duration is presented in Table 4 and Graph 3.

Table 4. Symptom duration before clinical presentation.

Variables	Values
Mean duration (days)	29.8 ± 59.3
Range (days)	1 - 420



Graph 3. Clinical presentation symptoms duration before surgical intervention.

Based on Graph 3, the mean duration from symptom onset to surgery was 29.8 ± 59.3 days (range, 1 - 420 days), and the distribution was markedly right-skewed, with most eyes undergoing surgery within a relatively short period after symptom onset. However, several extreme values were observed, indicating that a subset of eyes presented substantially later. The presence of numerous outliers above the upper quartile contributed to the wide range and high variability observed in symptom duration [19].

3.7. Systemic and Ocular Comorbidities

The prevalence of systemic and ocular comorbidities and their preoperative clinical characteristics of the study population of eyes with RRD are summarized in Table 5. Macula-off retinal detachment and Grade B proliferative vitreoretinopathy were the most common presentations, while a single retinal break was identified in the majority of eyes. Arterial hypertension was the most prevalent systemic comorbidity, followed by myopia and diabetes mellitus.

Table 5. Distribution of systemic and ocular comorbidities in the study.

Variables	Number of eyes, and (%)
Macula-Off	150 (77.7%)
Macula-On	43 (22.3%)
PVR Grade A	65 (33.7%)
PVR Grade B	83 (43.0%)
PVR Grade C	45 (23.3%)
Single retinal break	121 (62.7%)
Two retinal breaks	20 (10.4%)

Continued

Three-four retinal breaks	30 (15.5%)
≥5 retinal breaks	22 (11.4%)
Diabetes Mellitus	29 (15.0%)
Hypertension	109 (56.5%)
Myopia	62 (32.1%)

As shown in Table 5, arterial hypertension was present in 109 (56.5%) eyes, while 84 (43.5%) eyes had no documented history of hypertension. Myopia was identified in 62 (32.1%) eyes, whereas 131 (67.9%) eyes had no history of myopia.

3.8. Surgical Characteristics and Techniques

A total of 193 eyes underwent surgical repair for RRD. PPV was the predominant surgical technique, performed in 167 (86.5%) eyes, whereas PR was used in 26 (13.5%) eyes.

Silicone oil was the most frequently used intraocular tamponade, accounting for 159 (82.4%) eyes, while perfluoropropane gas (C_3F_8) was used in 34 (17.6%) eyes. Among adjunctive surgical procedures, endolaser photocoagulation was performed in 170 (88.1%) eyes, whereas cryotherapy was used in 31 (16.1%) eyes. Internal limiting membrane (ILM) and/or epiretinal membrane (ERM) peeling was performed in 18 (9.3%) eyes. Endolaser photocoagulation was performed in the vast majority of eyes to achieve permanent chorioretinal adhesion around retinal breaks. In contrast, cryotherapy was used less frequently and was reserved for selected cases according to intraoperative findings.

Internal limiting membrane (ILM) and/or epiretinal membrane (ERM) peeling were performed in a subset of eyes when clinically indicated. All of the above data were shown in Table 6. The decision to perform membrane peeling was based on the presence of macular pathology, tractional components, or surgeon assessment during surgery, with consideration of the surgical technique and socioeconomic status [20].

Table 6. Surgical characteristics of the study.

Variables	Number of eyes, and (%)
Pars plana vitrectomy (PPV)	167 (86.5)
Pneumatic retinopexy (PR)	26 (13.5)
Silicone oil tamponade	159 (82.4)
C3F8 gas tamponade	34 (17.6)
Endolaser photocoagulation	170 (88.1)
No endolaser	23 (11.9)
Cryotherapy	31 (16.1)

Continued

No cryotherapy	162 (83.9)
ILM/ERM peeling	18 (9.3)
No ILM/ERM peeling	175 (90.7)

3.9. Anatomical Outcomes

Anatomical outcomes were evaluated to assess the effectiveness of surgical management in achieving and maintaining retinal reattachment. Outcome measures included primary anatomical success, defined as retinal attachment following a single surgical procedure, and the incidence of recurrent retinal detachment during follow-up. Anatomical results were further analyzed according to surgical technique and PVR grade.

3.10. Primary Anatomical Success

Primary anatomical success, defined as retinal reattachment after a single surgical intervention, was achieved in 170 of 193 (88.1%) eyes. Retinal redetachment occurred in 23 (11.9%) eyes, during follow-up, as shown in Table 7.

Table 7. Primary anatomical success.

Outcomes	Number of eyes	Percentage (%)
Primary anatomical success	170	88.1
Retinal redetachment	23	11.9
Total	193	100

The anatomical outcome according to surgical technique is presented in Table 8. Primary anatomical success was achieved in 152 of 167 (91.0%) eyes treated with PPV, and in 18 of 26 (69.2%) eyes treated with PR. Retinal redetachment occurred in 15 (9.0%) eyes, and 8 (30.8%) eyes respectively [13] [14]. The difference in anatomical success between the two surgical techniques was statistically significant P = 0.004.

Table 8. Anatomical success according to surgical technique.

Surgical Technique	N-total eyes	Primary anatomical Success, n (%)	Number of redetachment, (%)	P-value
Pars plana vitrectomy (PPV)	167	152 (91.0)	15 (9.0)	
Pneumatic retinopexy (PR)	26	18 (69.2)	8 (30.8)	
Total	193	170 (88.1)	23 (11.9)	0.004

Anatomical outcomes according to proliferative vitreoretinopathy (PVR) grade are summarized in Table 9. Primary anatomical success was observed in 57 (87.6%) 65 eyes with PVR Grade A, 76 (91.5%) 83 eyes with PVR Grade B, and 36 (80.0%) 45 eyes with PVR Grade C. Retinal redetachment occurred in 8 (12.4%) with Grade A, 7 (8.5%) eyes with Grade B, and 9 (20%) eyes with Grade C respectively [12] [15]. No statistically significant association was found between PVR grade and primary anatomical outcome P = 0.683.

Table 9. Anatomical success according to PVR grade.

PVR Grade	Total eyes (n)	Primary anatomical success, N, (%)	Redetachment, N, (%)
Grade A	65	57 (87.6)	8 (12.4)
Grade B	83	76 (91.5)	7 (8.5)
Grade C	45	36 (80.0)	9 (20.0)
Total	193	169 (87.6)	24 (12.4)

3.11. Time to Redetachment

Retinal redetachment is a clinically significant postoperative complication and represents the principal indicator of anatomical failure following surgical repair of RRD. Among eyes that developed recurrent retinal detachment, the mean time to redetachment was 31.6 ± 37.1 days, ranging from 1 to 120 days. A summary of anatomical outcomes is presented in Table 10.

Table 10. Summary of primary anatomical outcomes and mean time of redetachment.

Variables	n (%)/Mean ± SD
Primary anatomical success	169 (87.6%)
Redetachment	24 (12.4%)
Mean time to redetachment (days)	31.6 ± 37.1
Range (days)	1 - 120

3.12. Comparison between Eyes with and without Redetachment

Baseline characteristics according to redetachment status are summarized in Table 11. No significant differences were observed between groups regarding age, macular status, or PVR grade. In contrast, surgical technique, tamponade type, and endolaser application were significantly associated with redetachment. Eyes with recurrent detachment were more frequently treated with PR, received C_3F_8 gas tamponade, and were less likely to undergo endolaser photocoagulation.

Table 11. Baseline characteristics according to redetachment status.

Characteristic	Redetachment (n = 170)	Redetachment (n = 23)	P-values
Age, years	59.2 ± 11.1	59.7 ± 12.0	NS
Macula-off	135 (79.4%)	15 (65.2%)	0.178

Continued

Macula-on	35 (20.6%)	8 (34.8%)	
PVR Grade A	58 (34.1%)	8 (34.8%)	
PVR Grade B	77 (45.3%)	8 (34.8%)	
PVR Grade C	35 (20.6%)	7 (30.4%)	0.493
PPV	152 (89.4%)	15 (65.2%)	0.004
Pneumatic Retinopexy	18 (10.6%)	8 (34.8%)	
Silicone Oil	146 (85.9%)	13 (56.5%)	
C3F8 Gas	24 (14.1%)	10 (43.5%)	0.001
Endolaser	154 (90.6%)	16 (69.6%)	0.010
No Endolaser	16 (9.4%)	7 (30.4%)	

3.13. Independent Predictors of Redetachment

Multivariabele logistic regression analysis identified PVR Grade C as the only independent predictor of retinal redetachment (OR = 3.35, 95% CI: 1.09 - 10.33; P = 0.036). No independent associations were observed for age, macular status, surgical technique, tamponade type, or endolaser application after adjustment for potential confounders, these data are presented in Table 12.

Table 12. Multivariate logistic regression analysis for redetachment.

Variables	Adjusted OR	95% CI	P-values
Age	1.01	0.97 - 1.05	0.688
Macula-off RRD	0.69	0.24 - 2.00	0.493
PVR Grade C	3.35	1.09 - 10.33	0.036
Pneumatic Retinopexy vs PPV	1.02	0.09 - 11.06	0.988
Silicone Oil (vs C3F8)	0.20	0.03 - 1.26	0.087
Endolaser	0.74	0.09 - 6.26	0.781

3.14. Functional Outcomes: Best-Corrected Visual Acuity (BCVA)

Visual outcomes are summarized in Table 13. Mean preoperative BCVA was 1.90 ± 0.65 logMAR, and improved to 0.57 ± 0.61 logMAR, at the final follow-up (≥6 months). The mean visual improvement was 1.33 logMAR units, indicating a significant functional gain following surgical repair of rhegmatogenous retinal detachment $P < 0.001$.

Table 13. Preoperative and postoperative BCVA outcomes.

Variables	Mean ± SD (logMAR)
Preoperative BCVA	1.90 ± 0.65
Postoperative BCVA (≥6 months)	0.57 ± 0.61
Mean Improvement	1.33
p-value	<0.001

3.15. Predictors of Final Visual Acuity

A multivariabele linear regression analysis was performed to identify independent predictors of final postoperative BCVA. As shown in Table 14, symptom duration, macular status, and retinal redetachment were independently associated with final visual outcomes.

Table 14. Multivariate linear regression analysis for final BCVA.

Variable	β-coefficient	95% CI	P-values
Age	0.003	−0.003 to 0.009	0.342
Symptom Duration (days)	0.0033	0.0020 to 0.0045	<0.001
Macula-off RRD	0.340	0.157 to 0.523	<0.001
Pneumatic Retinopexy (vs PPV)	0.042	−0.183 to 0.266	0.715
Retinal Redetachment	0.545	0.314 to 0.776	<0.001
PVR Grade	0.095	−0.010 to 0.201	0.076

Longer symptom duration before surgery was significantly associated with worse postoperative BCVA ($\beta = 0.0033$, 95% CI: 0.0020 - 0.0045; $P < 0.001$). Similarly, eyes presenting with macula-off retinal detachment achieved poorer final visual acuity compared with macula-on cases ($\beta = 0.340$, 95% CI: 0.157 - 0.523; $P < 0.001$). Retinal redetachment was also independently associated with poorer final BCVA, with a β coefficient of 0.545 (95% CI: 0.314 - 0.776; $P < 0.001$).

No statistically significant independent associations were identified for age, surgical technique, or PVR Grade. PVR Grade showed a borderline association with final BCVA, but did not reach statistical significance ($P = 0.076$).

3.16. Predictors of Functional Success

A multivariable logistic regression analysis was performed to identify independent predictors of functional success, defined as a final BCVA ≤ 0.3 logMAR. As shown in Table 15, macular status, PVR severity, and postoperative retinal redetachment were significantly associated with functional outcome.

Macula-off retinal detachment was associated with lower odds of achieving functional success (OR = 0.43, 95% CI: 0.19 - 0.97; $P = 0.042$). Similarly, eyes with PVR Grade C had lower odds of achieving functional success compared with eyes without Grade C PVR (OR = 0.41, 95% CI: 0.19 - 0.91; $P = 0.028$). Postoperative retinal redetachment was the strongest independent predictor of reduced functional success (OR = 0.13, 95% CI: 0.04 - 0.45; $P = 0.001$).

Table 15. Multivariate logistic regression analysis for functional success (BCVA ≤ 0.3 logMAR).

Variable	Adjusted OR	95% CI	P-value
Age	0.98	0.96 - 1.01	0.228
Macula-off RRD	0.43	0.19 - 0.97	0.042
PVR Grade C	0.41	0.19 - 0.91	0.028
Pneumatic Retinopexy (vs PPV)	1.89	0.65 - 5.49	0.243
Retinal Redetachment	0.13	0.04 - 0.45	0.001

Age and surgical technique were not independently associated with functional success after multivariable adjustment.

3.17. Performance of the Final BCVA Regression Model

Model performance metrics are summarized in Table 16. Of the 193 eyes included in the study, 190 had complete data, and were included in the regression analysis. The model was statistically significant ($F = 15.99$, $P < 0.001$) and explained 34.4% of the variability in final BCVA ($R^2 = 0.344$). The adjusted R^2 of 0.322 indicated satisfactory model stability.

3.18. Time-to-Event Analysis of Retinal Redetachment

Survival analysis is widely used in vitreoretinal research to evaluate the temporal pattern and risk factors associated with postoperative retinal redetachment. Accordingly, Kaplan-Meier analysis was performed to assess redetachment-free survival, and Cox proportional hazards regression was used to evaluate predictors of recurrence. Given, the limited number of postoperative retinal redetachment, the recurrence analysis was re-specified using a parsimonious multivariable time-to-event approach.

Table 16. Metric performance to multivariate regression model for final BCVA.

Metric	Values
Total study population	193 eyes
Eyes included in regression	190 eyes
R^2	0.344
Adjusted R^2	0.322
F-statistic	15.99
Model P-value	$P < 0.001$

3.19. Kaplan-Meier Survival Analysis

Kaplan-Meier survival analysis was performed to evaluate redetachment-free survival following surgical repair of RRD [21] [22]. During follow-up, 23 (11.9%) eyes developed recurrent retinal detachment. The median time to recurrence was 18 days (IQR: 7 - 53 days), whereas the mean time to recurrence was 31.8 ± 33.4 days (range: 1 - 120 days) The Kaplan-Meier survival analysis according to surgical technique is presented is presented in Table 17.

Table 17. Kaplan-Meier survival analysis according to surgical technique.

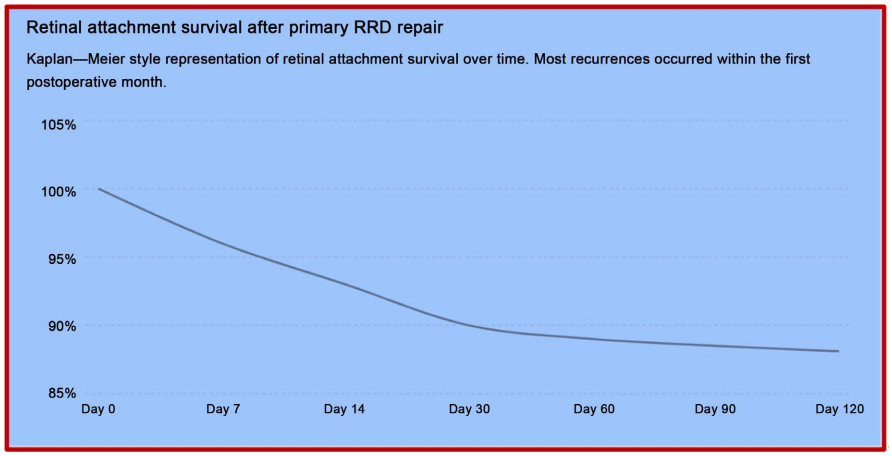
Time (days)	0	30	60	90	120	180
Number at risk	193	178	173	171	170	169

The Kaplan-Meier curve demonstrated that most redetachment events occurred during the early postoperative period, with the greatest decline in retinal

attachment survival observed within the first month after surgery. Thereafter, the survival curve progressively plateaued, indicating a substantially lower risk of recurrence during later follow-up. Furthermore, eyes treated with pars plana vitrectomy exhibited a higher probability of redetachment-free survival compared with those treated with PR, consistent with the findings of the Cox proportional hazards model (HR = 4.62, 95% CI: 1.96 - 10.91; P = 0.0005) (see Graph 4).

3.20. Adjusted Cox Proportional Hazards Regression Analysis

To further assess the effect of surgical technique on the risk of retinal redetachment over time, a Cox proportional hazards regression model was performed. PR was associated with an increased hazard of retinal redetachment compared with PPV, with the adjusted hazard ratio and 95% confidence interval as reported in Table 18 (HR = 4.62, 95% CI: 1.96 - 10.91; P = 0.0005).



Graph 4. Kaplan-Meier redetachment-free survival curve according to surgical technique.

Table 18. Cox proportional hazards regression analysis for retinal redetachment.

Variable	Hazard ratio (HR)	95% CI	P-value
Pneumatic Retinopexy **vs** PPV	4.62	1.96 - 10.91	0.0005

For the time-to-event analysis of postoperative retinal redetachment, the date of the primary retinal detachment surgery was defined as the time origin (day 0). The event was defined as the first clinically documented retinal redetachment after the primary surgical procedure. Eyes without documented redetachment were right-censored at the date of their last available postoperative follow-up. A multivariable Cox proportional hazards regression model was used to provide an adjusted time-to-event analysis. Given the limited number of redetachment events, the model was restricted to a parsimonious set of clinically relevant prespecified covariates. The proportional hazards assumption was assessed using Schoenfeld residuals.

3.21. Comparative Visual and Anatomical Outcomes According to Surgical Technique

Given the observed differences in anatomical success and redetachment rates, a comparative analysis of outcomes according to surgical technique was subsequently performed. The comparative analysis of anatomical and functional outcomes according to surgical technique is presented in Table 19.

Of the 193 eyes included in the study, 167 (86.5%) eyes underwent PPV, whereas 26 (13.5%) were treated with PR.

Primary anatomical success was significantly higher in the PPV group than in the PR group (91.0% vs. 69.2%; P = 0.004). Consequently, retinal redetachment and the need for additional interventions occurred more frequently following PR (30.8% vs. 9.0%; P = 0.004 for both comparisons).

In contrast, no significant differences were observed between treatment groups regarding final BCVA or mean visual improvement (both P > 0.05).

Table 19. Comparison of anatomical & functional outcomes according to surgical technique.

Variable	PPV (n = 167)	PR (n = 26)	P-value
Primary anatomical success, n (%)	152 (91.0)	18 (69.2)	0.004
Retinal redetachment, n (%)	15 (9.0)	8 (30.8)	0.004
Final BCVA (logMAR), mean ± SD	0.54 ± 0.59	0.43 ± 0.59	0.39
Mean BCVA improvement (logMAR)	1.46 ± 0.92	1.58 ± 0.88	0.57
Additional interventions required, n (%)	15 (9.0)	8 (30.8)	0.004

While in Figure 2, visually are demonstrates the change in best-corrected visual acuity between baseline and final follow-up examinations.

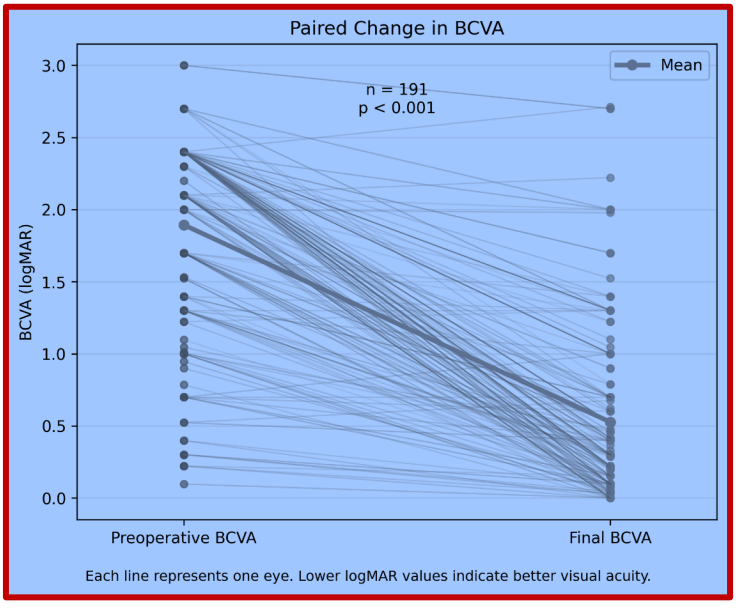


Figure 2. Change in best-corrected visual acuity following surgical repair.

Figure 2 demonstrates the paired change in BCVA between baseline and final follow-up. Mean visual acuity improved significantly from 1.90 ± 0.65 logMAR preoperatively to 0.57 ± 0.61 logMAR postoperatively, representing a mean gain of 1.33 logMAR units ($P < 0.001$). Most eyes exhibited functional improvement, as reflected by the downward shift in logMAR values at the final assessment.

4. Experience with the PR Treatment Modality and Its Role in Our Center

4.1. Pneumatic Retinopexy: Clinical Implementation and Outcomes

Pneumatic retinopexy (PR) was introduced as a treatment option for selected eyes of primary RRD at the "Albanian Eye Center", following established anatomical and clinical eligibility criteria. Of the 193 eyes included in the study, 26 (13.5%) eyes underwent PR, whereas 167 (86.5%) eyes were treated with PPV [13]-[15].

Patient selection was based on the presence of superior retinal breaks located between the 8 and 4 o'clock meridians, a single break or a cluster of breaks within one clock hour, retinal detachment involving no more than two quadrants, and the absence of advanced PVR. Additional requirements included clear ocular media, adequate visualization of the retinal periphery, short symptom duration, and the ability to maintain postoperative positioning.

Among the 26 eyes treated with PR, the mean age was 58.6 ± 11.8 years (range, 23 - 79 years), and 56% were male. The majority originated from rural areas (69%). Primary anatomical success was achieved in 69.2% of eyes, whereas retinal redetachment occurred in 30.8% of the eyes. Despite a lower anatomical success rate compared with PPV, PR was associated with substantial visual improvement and favorable final visual acuity in appropriately selected cases. Overall, these findings support the role of PR as a treatment option for selected RRD eyes. While the PPV remained the preferred approach for complex retinal detachments, PR provided satisfactory functional outcomes when strict selection criteria were applied.

4.2. Factors Associated with Pneumatic Retinopexy Failure

Among the 26 eyes treated with PR, primary anatomical success was achieved in 18 (69.2%) eyes, whereas 8 (30.8%) eyes developed recurrent retinal detachment. The comparison between successful and failed PR cases is summarized in Table 20.

Table 20. Factors associated with pneumatic retinopexy failure.

Variables	Successful PR (n = 18)	Failed PR (n = 8)	P-value
Age (years), mean	57.3	57.4	0.824
Symptom duration (days), mean	6.6	13.1	0.003
Preoperative BCVA (logMAR), mean	1.31	1.32	1.000
Final BCVA (logMAR), mean	0.28	0.78	0.171
Macula-off RRD, n (%)	8 (44.4)	4 (50.0)	1.000
PVR Grade B/C, n (%)	4 (22.2)	4 (50.0)	0.197

Eyes with treatment failure had a significantly longer duration of symptoms before surgery compared with successfully treated eyes (13.1 vs. 6.6 days; P = 0.003). No significant differences were observed regarding age, preoperative BCVA, macular status, or PVR grade all P > 0.05, although higher PVR grades were more frequent among failed cases. Final BCVA tended to be poorer in eyes with failed PR (0.78 vs. 0.28 logMAR), without reaching statistical significance [14]-[16]. Overall, delayed presentation emerged as the only factor significantly associated with PR failure in this subgroup.

4.3. Visual Outcomes in the PR Subgroup

Among the 26 eyes treated with PR, primary anatomical success was achieved in 18 (69.2%) eyes, whereas 8 (30.8%) eyes developed retinal redetachment. Final BCVA was poorer among eyes with treatment failure than among successfully treated eyes (0.78 vs. 0.28 logMAR), although this difference did not reach statistical significance (P = 0.171). Longer symptom duration was significantly associated with PR treatment failure (13.1 vs. 6.6 days; P = 0.003). These findings provide exploratory information regarding visual and anatomical outcomes within the selected PR subgrup [23]. Because PR was applied to a relatively small, clinically selected subgroup, these observations were interpreted separately from the primary multivariable analysis performed in the entire study population. In the overall cohort, surgical technique was not independently associated with final BCVA after multivariable adjustment.

5. Discussion

Main Findings. This retrospective cohort study evaluated anatomical and functional outcomes following RRD repair and identified factors associated with postoperative recurrence and visual recovery. Primary anatomical success was achieved in 87.6% of eyes, while retinal redetachment occurred in 12.4% of eyes during follow-up. PPV yielded superior anatomical outcomes compared with PR, while PVR Grade C was the only independent predictor of postoperative retinal redetachment. Longer symptom duration, macula-off RRD, and postoperative retinal redetachment were independently associated with poorer final visual acuity. In addition, macula-off RRD, PVR Grade C, and postoperative retinal redetachment were independently associated with lower odds of achieving functional success. These findings are consistent with those of Peck *et al.* [24], who reported that preoperative PVR severity, macular involvement, and the extent of retinal detachment are key determinants of both anatomical success and postoperative visual recovery, underscoring the importance of early surgical intervention before advanced disease develops. The prevalence of systemic and ocular comorbidities in study population including: arterial hypertension and diabetes mellitus was also consistent with contemporary literature [19] [20].

Anatomical Success. The overall anatomical success observed in this cohort is comparable with outcomes reported in contemporary vitreoretinal literature, sup-

porting the effectiveness of current surgical strategies for primary RRD repair. The age distribution in our cohort, with a predominance of eyes among patients in the sixth and seventh decades, is consistent with previous epidemiological studies reporting an increased incidence of RRD with advancing age and vitreoretinal degenerative changes [1] [2]. Postoperative retinal redetachment remains a clinically significant complication, particularly in eyes presenting with advanced retinal pathology. These findings are consistent with the systematic review by Huang *et al.* [25], which demonstrated high primary retinal reattachment rates following PPV for uncomplicated RRD, irrespective of the tamponade agent used, while reporting superior functional outcomes with gas tamponade. Collectively, these findings reinforce the effectiveness of modern vitreoretinal surgical techniques in achieving favorable anatomical outcomes while emphasizing the persistent influence of disease severity on surgical prognosis.

PPV vs Pneumatic Retinopexy. In the present cohort, PPV was associated with a higher rate of primary anatomical success and a lower rate of retinal redetachment than PR. However, these differences should be interpreted in the context of non-randomized treatment allocation and potential confounding by indication. PR was preferentially used in carefully selected eyes with favorable anatomical characteristics, whereas PPV was more frequently performed in eyes requiring more comprehensive surgical management. Therefore, the observed differences in anatomical outcomes between PPV and PR should be interpreted as associations rather than evidence of treatment superiority. Surgical technique was associated with anatomical outcomes, although comparisons between PPV and PR should be interpreted cautiously because treatment allocation was clinically selected and therefore susceptible to confounding by indication. The comparison was further evaluated using prespecified clinical factors that may influence treatment selection and outcomes, including macular status, PVR severity, retinal break configuration, detachment extent, lens status, and symptom duration. Accordingly, any adjusted association between surgical technique and outcome should be interpreted in the context of these baseline clinical characteristics. The relatively small number of eyes treated with PR also limits the precision of adjusted estimates and warrants cautious interpretation [6] [7].

Limitations. Our study has several limitations that should be considered when interpreting the findings. *First*, treatment selection was influenced by clinical indication, particularly in the choice between PPV and PR, introducing potential selection bias and residual confounding. *Second*, the PR subgroup was relatively small, comprising 26 of the 193 included eyes, which limited the statistical power of subgroup analyses. *Third*, the limited number of retinal redetachment events constrained the complexity of the multivariable recurrence models. *Fourth*, follow-up duration varied among eyes, which may have influenced the detection of late postoperative events. *Fifth*, the single-center design may limit the generalizability of the findings to other clinical settings. *Finally*, despite adjustment for clinically relevant variables, residual confounding from unmeasured or incompletely

measured factors cannot be excluded.

Pneumatic Retinopexy Subgroup. PR was performed in a carefully selected subgroup of the eyes patients and achieved favorable functional outcomes despite a lower primary anatomical success rate than PPV. Within this subgroup, delayed presentation was significantly associated with treatment failure, highlighting the importance of timely intervention. These findings are consistent with current evidence indicating that PR is an effective treatment for selected uncomplicated RRD, provided that strict eyes selection and appropriate surgical timing are maintained [6] [7].

Predictors of Retinal Redetachment. Advanced PVR was important independent predictor of postoperative retinal redetachment, confirming its central role in anatomical failure after RRD surgery. Although PR was associated with a higher recurrence rate in univariate analyses, this association disappeared after multivariable adjustment, suggesting that disease severity rather than surgical technique primarily determines the risk of recurrence. This interpretation is consistent with the findings of the Pneumatic Retinopexy versus Vitrectomy for the Management of Primary RRD Outcomes randomized trial (PIVOT), in which anatomical outcomes were shown to depend substantially on appropriate patient selection and baseline clinical characteristics rather than on the surgical technique alone [26]. Nearly one-quarter of eyes presented with advanced PVR (Grade C), reflecting the complexity of RRD at referral. This finding is consistent with previous literature emphasizing the clinical importance of advanced PVR in complex retinal detachment [17] [18]. In addition, a recent systematic review and meta-analysis by Xiang *et al.* [27] identified preoperative PVR as the strongest and most consistent predictor of postoperative failure, further supporting the concept that the biological severity of retinal detachment is a more important determinant of anatomical success than the choice of surgical procedure.

Kaplan-Meier Survival and Cox Proportional Hazards Analysis. Time-to-event analysis demonstrated that most retinal redetachments occurred during the first postoperative month, after which the Kaplan-Meier survival curve remained relatively stable, indicating a markedly lower risk of recurrence during later follow-up. This pattern is consistent with recent evidence showing that postoperative failures are concentrated in the early healing phase, when residual vitreoretinal traction and early proliferative vitreoretinopathy are most likely to compromise anatomical success [21]. Cox regression demonstrated a higher hazard of recurrence following pneumatic retinopexy; however, this finding should be interpreted cautiously because treatment selection was influenced by baseline disease characteristics. Similarly, recent studies have suggested that postoperative recurrence is driven predominantly by preoperative disease severity and established risk factors rather than by the surgical technique itself [21] [22]. The Kaplan-Meier curve demonstrated that most redetachment events occurred during the early postoperative period, with the greatest decline in retinal attachment survival observed within the first month after surgery. Thereafter, the survival curve progressively plateaued, indicating a substantially lower risk of recurrence during

later follow-up. Furthermore, eyes treated with PPV exhibited a higher probability of redetachment-free survival compared with those treated with PR, consistent with the findings of the Cox proportional hazards model. These findings support close postoperative surveillance during the first month after surgery, particularly in eyes at high risk of recurrence [22].

Functional Outcomes. Significant improvement in postoperative BCVA confirmed the functional benefit of retinal reattachment surgery. Nevertheless, visual recovery varied substantially among eyes, indicating that successful anatomical repair does not necessarily translate into optimal functional outcomes. Similar observations have been consistently reported in contemporary studies of RRD.

Macular Status, Visual Acuity Recovery and Prognosis. These findings indicate that macular involvement, delayed presentation, and postoperative retinal redetachment were independently associated with poorer final BCVA. These findings reinforce the importance of early diagnosis and prompt surgical intervention to preserve macular function and maximize visual recovery. Furthermore, recurrent retinal detachment remained the strongest determinant of unfavorable visual prognosis, highlighting that prevention of postoperative recurrence should remain a primary objective of vitreoretinal surgery.

6. Conclusions

The present study demonstrates that contemporary surgical management of RRD achieves high rates of anatomical success together with significant postoperative visual improvement. PVR Grade C was independently associated with postoperative retinal redetachment, while longer symptom duration, macula-off RRD, and postoperative retinal redetachment were independently associated with poorer final BCVA. Furthermore, macula-off RRD, PVR Grade C, and postoperative retinal redetachment were associated with lower odds of achieving functional success. These findings emphasize the importance of timely diagnosis, early surgical intervention, and prevention of postoperative recurrence [28].

Surgical technique was associated with anatomical outcomes, although comparisons between PPV and PR should be interpreted cautiously because treatment allocation was clinically selected and therefore susceptible to confounding by indication. PPV provided greater anatomical stability and lower recurrence rates, supporting its use as an appropriate surgical strategy for anatomically complex rhegmatogenous retinal detachments. In contrast, PR achieved satisfactory functional outcomes in appropriately selected eyes, supporting its role as an effective minimally invasive alternative when anatomical and clinical selection criteria are carefully met. These findings are consistent with recent evidence indicating that successful management of RRD depends on matching the surgical technique to the anatomical characteristics and clinical complexity of each case, with the outcomes of PR being largely determined by meticulous patient selection [29].

As a tertiary vitreoretinal referral center managing both routine and complex cases of RRD, our experience underscores the importance of individualized surgical decision making based on retinal pathology, disease severity, and patient-

specific characteristics. Such an approach may optimize both anatomical reattachment and visual recovery while facilitating appropriate selection of patients for PR, in line with contemporary evidence supporting patient-tailored surgical management of RRD [30].

Furthermore, this study represents one of the first comprehensive reports from Albania evaluating the role of PR within contemporary vitreoretinal practice and provides regional evidence supporting individualized surgical management of RRD. Future prospective, multicenter studies with larger cohorts are warranted to validate these findings and further refine patient selection criteria for the different surgical approaches.

Ethics Approval and Consent to Participate

For the retrospective component, involving the secondary analysis of existing clinical records of eyes that underwent surgical treatment for RRD between 2022 and 2024, access to the relevant clinical records was formally authorized by the Clinic Medical Administrator, Dr. Orjeta Tonuzi, the Administrative Medical Director, Prof. Ali Tonuzi, and the corresponding author, who are responsible for the management and oversight of the institution's medical records [Reference No. Date: 01 June 2024].

The prospective component, which commenced in June 2024 and involved direct patient contact, active re-evaluation, and prospective collection of clinical and ophthalmic outcome data, was conducted under the same institutional ethical framework. Patients, who were contacted for re-evaluation were informed about the purpose of the assessment and the use of their anonymized clinical information for research purposes was obtained from participating patients.

All data were anonymized before analysis to protect patient privacy and confidentiality. No personally identifiable information was accessed, collected, or reported in the study dataset or in any publication arising from the study.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are not publicly available due to ethical and institutional restrictions related to the protection of patient confidentiality. De-identified data supporting the findings of this study are available from the corresponding author or administrator of the "Albanian Eye Center" tertiary facility, upon reasonable request, subject to approval by the relevant institutional review board and in accordance with applicable data protection and ethical requirements.

Consent for Publication

Not applicable, because the manuscript does not present the individual clinical data or accompanying images obtained that could identify the participants included in the study.

Acknowledgements

The authors acknowledge the contribution of the clinical and technical staff of "Albanian Eye Center". Special appreciation is extended to Dr. Luan Qafmolla for his contribution to data management and editorial coordination.

Author Contributions

Conceptualization, surgical procedures, supervision, and critical revision were performed by Assoc. Prof. Ali Tonuzi, Ms. Migena Beqiri, MD, PhD, contributed for data collection and manuscript drafting. The finalization of the manuscript including literatures review was conducted by Dr. Luan Qafmolla.

Conflicts of Interest

All authors declare no conflict of interest related to study.

References

[1] Bellucci, C., Romano, A., Ramanzini, F., Tedesco, S.A., Gandolfi, S. and Mora, P. (2023) Pars Plana Vitrectomy Alone or Combined with Phacoemulsification to Treat RRD: A Systematic Review of the Recent Literature. *Journal of Clinical Medicine*, 12, 5021. https://doi.org/10.3390/jcm12155021

[2] Grad, J.R., Huan, P.W., Popovic, Muni, R.H, *et al.* (2024) Surgical Drainage Methods during Pars Plana Vitrectomy for RRD: A Systematic Review and Meta-Analysis. *Retina*, **44**, 747-755.

[3] Christensen, C.A., Thompson, I.A. and Nielsen, J.S. (2023) Small-Gauge Vitrectomy for Macular Surgery Using a Systematic Approach to Wound Closure: 27-Gauge vs 25-Gauge. *Journal of VitreoRetinal Diseases*, **8**, 45-50. https://doi.org/10.1177/24741264231209587

[4] Rai, R.S., Su, R., Gelnick, S., Lieberman, R.M. and Sheyman, A. (2023) Advances in Pneumatic Retinopexy. *Advances in Ophthalmology and Optometry*, **8**, 179-189. https://doi.org/10.1016/j.yaoo.2023.02.011

[5] Nishi, K., Nakamura, M. and Nishitsuka, K. (2023) Efficacy of Vitrectomy with Air Tamponade for Rhegmatogenous Retinal Detachment: A Prospective Study. *Scientific Reports*, **13**, Article No. 10790. https://doi.org/10.1038/s41598-023-37693-x

[6] Zinovios, K., Androudi, S., Karamitsos, A. and Mavrikakis, E. (2025) Pneumatic Retinopexy for the Management of Rhegmatogenous Retinal Detachment. *Cureus*, **17**, e94640.

[7] Shao, I., Dhoot, A.S., Popovic, M.M., Oquendo, P.L., Hamli, H., Kertes, P.J., *et al.* (2022) Pneumatic Retinopexy: A Review of an Essential Technique in Vitreoretinal Surgical Care. *Expert Review of Ophthalmology*, 17, 11-23. https://doi.org/10.1080/17469899.2022.2013817

[8] Li, K.K., Wong, D. and Steel, D.H.W. (2021) Silicone Oil in Rhegmatogenous Retinal Detachment Surgery. *Eye*, **35**, 2399-2412.

[9] Chronopoulos, A., Hattenbach, L.O. and Schutz, J.S. (2021) Pneumatic Retinopexy: A Critical Reappraisal. *Survey of Ophthalmology*, **66**, 585-593. https://doi.org/10.1016/j.survophthal.2020.12.007

[10] Warren, A., Wang, D.W. and Lim, J.I. (2023) Rhegmatogenous Retinal Detachment

Surgery: A Review. *Clinical & Experimental Ophthalmology*, **51**, 271-279. https://doi.org/10.1111/ceo.14205

[11] Popovic, M.M., Muni, R.H., Nichani, P. and Kertes, P.J. (2022) Pars Plana Vitrectomy, Scleral Buckle, and Pneumatic Retinopexy for the Management of Rhegmatogenous Retinal Detachment: A Meta-Analysis. *Survey of Ophthalmology*, **67**, 184-196. https://doi.org/10.1016/j.survophthal.2021.05.008

[12] Chereji, G., Samoilă, O. and Nicoară, S.D. (2025) Prognostic Factors for Visual Postsurgical Outcome in Rhegmatogenous Retinal Detachment—A Systematic Review. *Journal of Clinical Medicine*, **14**, Article 2016. https://doi.org/10.3390/jcm14062016

[13] Iannetta, D., Valsecchi, N., Finzi, A., Mastropasqua, R., Muni, R.H. and Fontana, L. (2024) Pneumatic Retinopexy for Primary Rhegmatogenous Retinal Detachment: From a Clinical Trial to the Real-Life Experience. *BMC Ophthalmology*, **24**, Article No. 287. https://doi.org/10.1186/s12886-024-03559-7

[14] Tonuzi, A. (2022) Protocol for the Management of Retinal Detachment: A Comprehensive Ophthalmic Surgical Approach at the "Albanian Eye Center". Technical Procedure.

[15] Baudin, F., Deschasse, C., Gabrielle, P., Berrod, J.P., Le Mer, Y., Arndt, C., *et al.* (2021) Functional and Anatomical Outcomes after Successful Repair of Macula-Off Retinal Detachment: A 12-Month Follow-Up of the DOREFA Study. *Acta Ophthalmologica*, **99**, 1190-1197. https://doi.org/10.1111/aos.14777

[16] Yorston, D., Donachie, P.H.J., Laidlaw, D.A., *et al.* (2021) Factors Affecting Visual Recovery after Successful Repair of Macula-Off Retinal Detachments: Findings from a Large Prospective UK Cohort Study. *Eye*, **35**, 1431-1439.

[17] Shahlaee, A., Woeller, C.F., Philp, N.J. and Kuriyan, A.E. (2022) Translational and Clinical Advancements in Management of Proliferative Vitreoretinopathy. *Current Opinion in Ophthalmology*, **33**, 219-227. https://doi.org/10.1097/icu.0000000000000840

[18] Sonmez, K. (2022) Outcomes and Predictors of Vitrectomy and Silicone Oil Tamponade in Retinal Detachments Complicated by Proliferative Vitreoretinopathy. *International Journal of Ophthalmology*, **15**, 1279-1289. https://doi.org/10.18240/ijo.2022.08.09

[19] Sultan, Z.N., Agorogiannis, E.I., Iannetta, D., Steel, D. and Sandinha, T. (2020) Rhegmatogenous Retinal Detachment: A Review of Current Practice in Diagnosis and Management. *BMJ Open Ophthalmology*, **5**, e000474. https://doi.org/10.1136/bmjophth-2020-000474

[20] Rahman, S., Sharma, N., Valentim, C.C.S., Muste, J.C., Iyer, A.I., Li, A., *et al.* (2023) Rhegmatogenous Retinal Detachment: Variations in Clinical Presentation and Surgical Outcomes by Socioeconomic Status and Race. *Ophthalmic Surgery, Lasers and Imaging Retina*, **53**, 538-545. https://doi.org/10.3928/23258160-20220923-01

[21] Tawfik, A.M., Eweidah, A.M., Hassanien, R.A., Mohamed, S.F., Kasem, R.A. and Ghoneem, M. (2025) Incidence and Risk Factors for Recurrence after Surgical Treatment of Rhegmatogenous Retinal Detachment: A Retrospective Cohort Study. *International Journal of Retina and Vitreous*, **11**, 59. https://doi.org/10.1186/s40942-025-00680-7

[22] Hébert, M., Garneau, J., Doukkali, S., Bourgault, S., Caissie, M., Tourville, É., *et al.* (2025) Outcomes in Recurrent Rhegmatogenous Retinal Detachment Repair: Does Scleral Buckling at Primary or Secondary Surgery Impact Results? *Clinical Ophthalmology*, **19**, 949-956. https://doi.org/10.2147/opth.s507985

[23] Chen, T.S., Motekalem, Y., Melo, I.M., Hillier, R.J., Berger, A.R., Giavedoni, L.R., *et al.* (2025) Long-Term Redetachment Rates of Pneumatic Retinopexy versus Pars Plana Vitrectomy in Retinal Detachment: A PIVOT Post Hoc Analysis. *Ophthalmology Retina*, **9**, 122-126. https://doi.org/10.1016/j.oret.2024.08.011

[24] Peck, T.J., Starr, M.R., Yonekawa, Y., Khan, M.A., Obeid, A., Ryan, E.H., *et al.* (2021) Outcomes of Primary Rhegmatogenous Retinal Detachment Repair in Eyes with Preoperative Grade B or C Proliferative Vitreoretinopathy. *Journal of VitreoRetinal Diseases*, **6**, 194-200. https://doi.org/10.1177/24741264211046770

[25] Huang, R.S., Mihalache, A., Lau, T.H.A., Popovic, M.M., Kertes, P.J. and Muni, R.H. (2024) PPV with Silicone Oil or Gas Tamponade for Uncomplicated Retinal Detachment: A Systematic Review and Meta-Analysis. *American Journal of Ophthalmology*, **266**, 144-155. https://doi.org/10.1016/j.ajo.2024.05.008

[26] Hillier, R.J., Felfeli, T., Berger, A.R., Wong, D.T., Altomare, F., Dai, D., *et al.* (2019) The Pneumatic Retinopexy versus Vitrectomy for the Management of Primary Rhegmatogenous Retinal Detachment Outcomes Randomized Trial (PIVOT). *Ophthalmology*, **126**, 531-539. https://doi.org/10.1016/j.ophtha.2018.11.014

[27] Xiang, J., Fan, J. and Wang, J. (2023) Risk Factors for Proliferative Vitreoretinopathy after Retinal Detachment Surgery: A Systematic Review and Meta-Analysis. *PLOS ONE*, **18**, e0292698. https://doi.org/10.1371/journal.pone.0292698

[28] Lin, J.B., Narayanan, R., Philippakis, E., Yonekawa, Y. and Apte, R.S. (2024) Retinal Detachment. *Nature Reviews Disease Primers*, **10**, Article No. 18. https://doi.org/10.1038/s41572-024-00501-5

[29] Zinovios, K., Androudi, S., Karamitsos, A. and Mavrikakis, E. (2025) Pneumatic Retinopexy for the Management of Rhegmatogenous Retinal Detachment. *Cureus*, **17**, e94640. https://doi.org/10.7759/cureus.94640

[30] Reeves, M.R., Afshar, A.R. and Pershing, S. (2021) Need for Retinal Detachment Reoperation Based on Primary Repair Method among Commercially Insured Patients, 2003-2016. *American Journal of Ophthalmology*, **229**, 71-81. https://doi.org/10.1016/j.ajo.2021.04.007