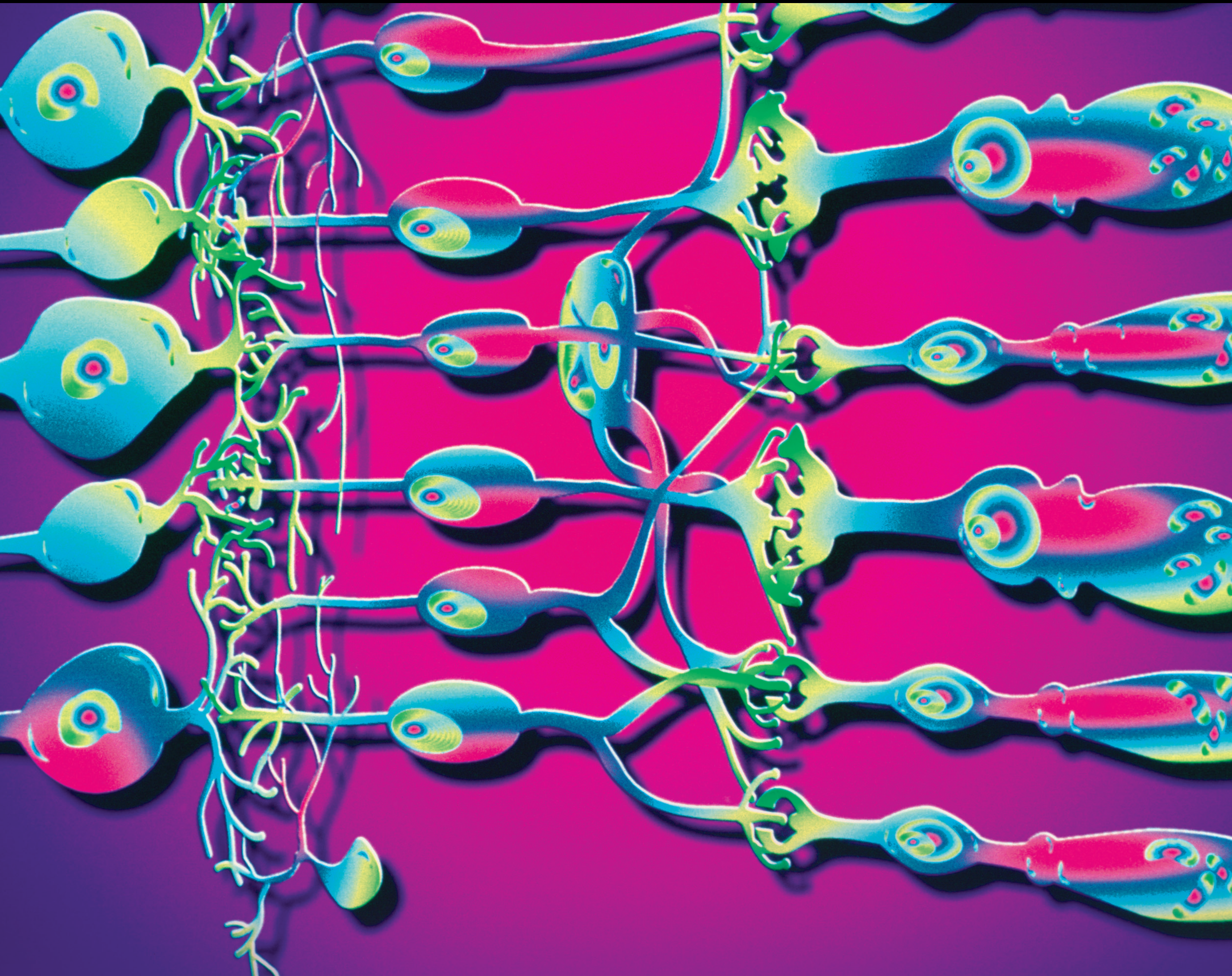
Journal of Ophthalmology

The Management of Retinal Detachment: Techniques and Perspectives 2018

Special Issue Editor in Chief: Elad Moisseiev
Guest Editors: Anat Loewenstein, Ala Moshiri, and Glenn Yiu



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https://doi.org/10.1155/2019/8185619

Editorial

The Management of Retinal Detachment: Techniques and Perspectives 2018

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Received 20 January 2019; Accepted 20 January 2019; Published 3 February 2019

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Retinal detachments are a common ocular condition that may have significant implication for patients' vision and wellbeing. They are frequently encountered by ophthalmologists of all subspecialties and possibly represent the quintessential challenge of vitreoretinal surgeons as these cases require early referral, thorough examination, a decision regarding the type of surgery, and properly timed intervention. Although surgical techniques have greatly improved over the years, surgery for retinal detachment repair remains technically challenging and requires skill, experience, and the proper instrumentation. About 60 years ago, retinal detachment was an incurable untreatable condition leading to irreversible vision loss, but today it is repairable in the vast majority of cases.

Advances in the understanding of retinal detachments and their treatment are continuously being made, with new instrumentation and techniques reported by many clinicians and researchers from all over the world. This annual special issue is intended to serve as a platform for sharing current data and new innovations in the management of retinal detachments.

In this issue, R. Kassem et al. performed a meta-analysis focusing on the timing of retinal detachment following cataract surgery. In their impressive study, which included more than 3 million eyes, the overall risk of retinal detachment following cataract surgery was found to be 1.16%, substantiating the known association between the two. The mean time for the occurrence of retinal detachment following cataract surgery was 1.5–2.3 years, and the authors suggest that proper timing of long-term follow-up after cataract surgery may assist in earlier detection of retinal detachment. The study also includes a comprehensive review of the literature on the association between cataract surgery and retinal detachment and the risk factors for this complication.

P. Kanclerz and A. Grzybowski contributed a thorough review on the use of gases in vitreoretinal surgery, covering their evolution, types, different characteristics, and alternatives. The review focuses on the possible complications of these gases, such as anterior chamber migration and endothelial damage, intraocular pressure elevation, cataract progression, and hypotony. This comprehensive review illuminates many of the important considerations that should be made when choosing and using gases in vitreoretinal surgery.

The use of 27-gauge systems for vitreoretinal surgery is gaining popularity, and two studies in this issue compared 27-gauge and 25-gauge vitrectomy for the repair of primary rhegmatogenous retinal detachment. D. Veritti et al. reported results of a prospective study including 74 eyes, and K. Otsuka et al. reported results of a retrospective study including 62 eyes, both with follow-up of over 6 months. In both studies, excellent results were achieved, with no difference in reattachment rates, visual improvement, or complications between the two systems. These results indicate the safety and efficacy of the 27-gauge instrumentation, which can be used for retinal detachment repair, and will likely increase in popularity in the near future.

Finally, V. Bonfiglio et al. reported an innovative technique for the repair of macula-on retinal detachments with intermediate breaks with vitreous traction. In this study, 32 such phakic eyes were treated by a limited 25-gauge vitrectomy, performed under air, releasing traction of the breaks and endolaser around them after the retina had reattached. All eyes were followed for 12 months, with excellent results comparable to those achieved by conventional vitrectomy. Importantly, none of the eyes demonstrated cataract progression, indicating this technique can be equally effective and safely used in select phakic patients.

Conflicts of Interest

The Guest Editors declare that there are no conflicts of interest regarding the publication of this special issue.

Acknowledgments

The Guest Editors would like to thank the authors of all the papers submitted to this special issue. We also wish to thank the many reviewers, who devoted their time, energy, and expertise and whose insightful comments helped improve the manuscripts selected for this special issue. We hope that the readers of this special issue will enjoy reading it and find its contents interesting and clinically valuable.

Elad Moisseiev
Anat Loewenstein
Ala Moshiri
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Hindawi
Journal of Ophthalmology
Volume 2019, Article ID 3120960, 6 pages
https://doi.org/10.1155/2019/3120960

Clinical Study

A Propensity-Score Matching Comparison between 27-Gauge and 25-Gauge Vitrectomy Systems for the Repair of Primary Rhegmatogenous Retinal Detachment

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Received 6 July 2018; Revised 17 November 2018; Accepted 19 December 2018; Published 10 January 2019

Guest Editor: Ala Moshiri

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Purpose. To compare the anatomical and visual results and complications of 27-gauge versus 25-gauge transconjunctival sutureless vitrectomy for the management of primary rhegmatogenous retinal detachment. *Methods*. A prospective, propensity score-matched 6-month study was performed. All patients underwent either 27-gauge or 25-gauge vitrectomy as the first surgical intervention and were followed up over a 6-month period, in order to evaluate anatomical success, change in best-corrected visual acuity (BCVA), and intraoperative and postoperative complications including intraocular pressure dysregulation. *Results*. Propensity score matching resulted in two groups of 37 eyes each. All eyes completed a six-month follow-up. Baseline demographic and preoperative ocular characteristics showed no statistically significant difference between the two cohorts. The single operation success rate was 33/37 (89%) for 27-gauge cases and 34/37 (92%) for 25-gauge cases ($p = 0.7$). The final anatomical success rate was 100% for each of the two cohorts. Mean BCVA change at the 6-month postoperative follow-up visit was −0.67 logMAR in the 27-gauge group and −0.71 logMAR in the 25-gauge group ($p = 0.9$). Two patients in the 25-gauge group experienced transient hypotony after surgery. *Conclusion*. No significant difference between 27-gauge and 25-gauge transconjunctival sutureless vitrectomy for the repair of primary rhegmatogenous retinal detachment was recorded in terms of reattachment rate, BCVA, intraoperative and postoperative complications.

1. Introduction

Rhegmatogenous retinal detachment (RRD) is defined as the separation of the neurosensory retina from the retinal pigment epithelium layer secondary to the presence of retinal breaks, allowing the accumulation of fluid in the subretinal space.

Over the past decades, the management of RRD has been revolutionized. Rhegmatogenous retinal detachment has changed from an untreatable condition leading to permanent vision loss to a repairable event after which visual improvement is very likely. A range of surgical techniques have been employed over the years to manage this sight-threatening pathology, including pneumatic retinopexy, scleral buckling, and pars plana vitrectomy (PPV) [1, 2]. Pars plana vitrectomy is nowadays the most commonly used procedure to repair primary RRD [3–5]. In the recent past, it has been progressively refined, thanks to technological progress, such as the development of small-gauge instrumentation and the use of high-speed probes. The main force driving PPV technical advancement is making a successful procedure less invasive, safer, with quicker recovery, and possibly improved outcomes. Indeed, smaller sutureless sclerotomy wounds result in less postoperative inflammation, improved patient comfort, and faster recovery.

Transconjunctival sutureless 27-gauge PPV has emerged as an important advancement in vitreoretinal surgery instrumentation [6, 7]. At the beginning, it was employed in noncomplex cases, such as vitreous hemorrhage and posterior pole procedures [7, 8]. More recently, surgeons advocate its use in more complicated conditions, including RRD requiring silicone oil tamponade [9–15].

Besides being less invasive when compared to 25-gauge PPV, 27-gauge PPV carries additional potential advantages, thanks to the design of the vitrectomy probe. It generates the shortest attraction distance and a smaller "sphere of influence" compared with 23-gauge and 25-gauge vitrectomy systems. This allows a more accurate fluid control and a greater dissection precision, theoretically allowing for safer procedures with reduced iatrogenic breaks [16].

However, 27-gauge vitrectomy also carries potential drawbacks when compared to 23-gauge and 25-gauge systems for the treatment of RRD. These limitations include a reduction in the flow rate potentially influencing the efficiency of the procedure, an increased instrument flexibility especially during anterior maneuvers, and the potential underfilling of tamponade [7, 17].

Evidence comparing 27-gauge to 25-gauge PPV for RRD is still limited [9–12]. Therefore, we designed and conducted the present study to compare the efficacy (in terms of reattachment rates after single or multiple surgeries) along with the safety of new high-speed 27-gauge PPV versus 25-gauge PPV for the repair of primary RRD in phakic and pseudophakic eyes.

2. Materials and Methods

2.1. Study Design. This is a 6-month, prospective, single-center, comparative, propensity score-matched study. It follows the tenets of the Declaration of Helsinki. Data were prospectively collected at the Department of Medicine-Ophthalmology, University of Udine, Udine, Italy. Patients with primary RRD were included in this study. Exclusion criteria were as follows: (1) inability to give informed consent; (2) previous ocular surgery excluding noncomplicated cataract extraction; (3) history of penetrating ocular trauma; (4) significant ocular comorbidities, such as uveitis, uncontrolled glaucoma, proliferative diabetic retinopathy, and proliferative vitreoretinopathy (PVR) greater than grade C accordingly to the updated Retina Society Classification [18]; (5) severe systemic disease.

Patients underwent either 27-gauge PPV or 25-gauge PPV, and we adopted a propensity score matching strategy to correct the selection biases and to compare the two groups. Propensity score method used a multivariable logistic regression model based on the following preoperative characteristics: age, macula status (on, off), lens status, presence and grade of PVR, number of retinal breaks, and best-corrected visual acuity (BCVA). Using predicted probabilities, we matched a participant in the 27-gauge group with the closest individual in the 25-gauge group using the nearest-neighbour matching technique.

2.2. Examinations. Preoperative evaluation consisted of a complete medical, surgical, and ophthalmic history followed by a thorough ophthalmic examination. Best-corrected visual acuity was measured using ETDRS charts and reported as logarithm of the minimum angle of resolution (logMAR). The updated Retina Society Classification was used to grade PVR, if present [18]. Patients were examined at baseline and then at days 1, 7, and 15 and at months 1, 3, and 6 after surgery.

2.3. Surgical Technique. All PPVs were performed under local anesthesia with a retrobulbar block. All surgeries were performed by the same surgeon (PL). Concurrent phacoemulsification and intraocular lens implantation were performed before vitrectomy if cataract was present. Surgical procedures were performed using the Alcon Constellation (Alcon, Forth Worth, TX, USA) under a Resight 700 (Carl Zeiss Meditec AG, Oberkochen, Germany) noncontact panoramic viewing system. Both the 27-gauge and 25-gauge procedures were performed using a three-port pars plana technique (the third port was used for a 25-gauge chandelier illuminator). Either 27-gauge or 25-gauge sclerotomies were created using the trocar cannula with a biplanar entry in order to create a self-sealing access. In detail, after displacement of the conjunctiva, oblique incisions at an angle of 45 degrees to the sclera with a two-step technique were performed.

The surgical parameters for both groups were the following: fixed cut rate of 7,500 cuts per minute (cpm), proportional vacuum of up to 650 mmHg, and intraocular pressure (IOP) at 35 mmHg. Posterior hyaloid detachment, core vitrectomy, and extensive peripheral vitrectomy over 360 degrees were performed in all cases. The vitreous base was meticulously shaved circumferentially in all cases with scleral depression. Any tears or suspicious retinal lesions were treated with endolaser photocoagulation or transscleral cryopexy. Perfluorocarbon liquid (PFCL) was used intraoperatively at surgeon discretion. After air-fluid exchange, 12% perfluoropropane (C_3F_8) gas, or 1,000 centistoke silicone oil was used as tamponade. At the end of the procedure, microcannulas were removed and a gentle massage of the sclerotomy with a cotton-tipped applicator was performed to avoid leakage; if any site showed persistent leakage, 7-0 vicryl sutures were placed.

2.4. Outcome Measures. The primary outcome measure was the retinal reattachment rate at month 6 (after single or multiple procedures). Cases were judged successful if retina's reattachment was maintained without tamponade agents.

Secondary outcomes were anatomical success at month 6 after a single procedure, operating time, rate of silicone oil utilization, BCVA at month 6, IOP dysregulation (hypotony/hypertony), and intraoperative and postoperative complications.

2.5. Statistical Analysis. Nonparametric tests (Wilcoxon test) and parametric tests (two-tailed t-test) were used to assess non-normally and normally distributed data, respectively. Dichotomous measures were compared using a chi-square test and Fisher's exact test. A p value of < 0.05 was defined as statistically significant.

3. Results

3.1. Subject Characteristics. The comprehensive pool of patients used to create the propensity score matching consisted of 114 eyes (41 in the 27-gauge group and 73 in the 25-gauge group). One-to-one matching according to the propensity score resulted in the two groups containing 37 eyes each. Baseline characteristics are listed in Table 1. As expected, due to the propensity score matching method, there was no preoperative statistically significant difference for each parameter between the two groups. All patients completed the 6-month follow-up.

3.2. Vitrectomy Outcomes. Retinal breaks could be identified in 100% of cases intraoperatively in both groups. Instrument sclerotomies were sutured in 3 cases (8%) in the 27-gauge group and in 11 cases (29%) in the 25-gauge group ($p = 0.017$). Twenty-five-gauge access for illuminated chandelier was excluded from analysis.

Operative time was comparable between the two groups (27-gauge: 86.1 ± 30.1 minutes; 25-gauge: 90.7 ± 29.6 minutes; $p = 0.5$). Perfluorocarbon liquid was given in all cases. In the 27-gauge group, 28 eyes (76%) had C3F8 gas tamponade and 9 eyes (24%) needed silicone oil. In the 25-gauge group, 30 eyes (81%) had C3F8 gas tamponade and 7 eyes (19%) had silicone oil tamponade (Table 2). The use of silicone oil was at the surgeon's discretion. It was used in cases with multiple, large, inferior breaks. Patients who received silicone oil tamponade underwent a second surgical procedure to remove the oil within 4 months from the initial surgery. At the final visit, no patient had silicone oil tamponade.

3.3. Anatomical Results. Anatomical success after a single operation at month 6 was 89% and 92% in the 27-gauge and in the 25-gauge groups, respectively. The difference was not statistically significant ($p = 0.7$). Recurrence of retinal detachment occurred in 4 eyes operated with a 27-gauge system and in 3 eyes in the 25-gauge group. All redetachments occurred within 3 months from the initial surgery. All patients presented with an attached retina at the 6-month follow-up visit (Table 2).

3.4. Visual Acuity Results. Best-corrected visual acuity changes are summarized in Figure 1. After the surgery, mean BCVA significantly improved in both groups ($p = 0.006$ and $p = 0.004$ in the 27-gauge and 25-gauge groups, respectively). Mean BCVA change at the 6-month postoperative follow-up visit was −0.67 logMAR in the 27-gauge group and −0.71 logMAR in the 25-gauge group ($p = 0.9$) (Table 2). At the 6-month visit, BCVA improved by more than 1 ETDRS line in 32 cases (86%) in the 25-gauge group and in 33 eyes (89%) in the 27-gauge group ($p = 0.7$). Vision was stable in the remaining cases. No visual acuity decrease of more than 5 ETDRS letters was recorded at the end of the follow-up.

3.5. Complications. No severe intraoperative complications occurred among the 74 eyes included in this analysis. The surgeon did not need to change the chosen instrumentation in any case. None of the eyes experienced significant intraocular inflammation after surgery. At day 1, no substantial differences in the amount of tamponade agents were noted in the two groups: a gas filling ≥90% was recorded in all (100%) eyes in the 27-gauge group and in 28 (93%) eyes in the 25-gauge group ($p = 0.6$). None of the patients in the 27-gauge group presented with IOP inferior to 10 mmHg on Goldmann applanation tonometry. Conversely, 2 cases experienced transient hypotony (IOP < 10 mmHg) in the 25-gauge group. Severe hypertension (IOP > 30 mmHg) was detected in 4 eyes (11%) in the 27-gauge group and in 5 eyes (14%) in the 25-gauge group during the follow-up (Table 2). In all cases, the raised IOP was transient and successfully treated with topical medications. No other postoperative complication was noted in the follow-up period in either group.

4. Discussion

The surgical management of RRD has come a long way over the past decades. Significant steps ahead have been made, and a variety of techniques are now available [19]. Recent years have witnessed a gradual increase in the application of small-gauge sutureless vitrectomy, which has now become a primary treatment modality in the management of RRD [3–5].

Recently, 27-gauge vitrectomy has been proposed for treatment of RRD. The main theoretical advantages of this technique are great precision of dissection maneuvers, effective fluidics, reduced postoperative inflammation and astigmatism, and improved wound integrity. However, concerns still exist and are related to operation efficiency, flexibility of instrumentation, and the possibility of wound leaks [9–14].

There are limited published data comparing the efficacy and safety of 27-gauge and 25-gauge PPV for RRD. Romano et al. [9] reported that the safety and efficacy of 27-gauge PPV for RRD appear similar to 25-gauge PPV. In both groups, anatomical success was obtained after a single round of surgery in 14 out of 15 eyes (93%). In another comparative study conducted by Rizzo et al. [10] on 40 eyes, the primary anatomical success rate after a single operation was 90.0% and 85.0% in the 27-gauge and in the 25-gauge groups ($p = 0.63$), respectively. Otsuka et al. recently published a retrospective study on comparing 25-gauge (32 eyes) and 27-gauge (30 eyes) PPV for primary RRD, finding no significant anatomical or functional differences with a primary success rate of 96.7% (25-gauge) and 93.8% (27-gauge) [12].

In this comparative, propensity score-matched study, we observed a comparable single-procedure success rate of 89% for the 27-gauge vitrectomy group and 92% for the 25-gauge group (no statistically significant difference). All retinas were flattened after an additional vitrectomy surgery at month 6.

The main benefit we noticed using 27-gauge systems is the increased precision of the surgical maneuvers. Dugel et al. [16] reported that smaller-gauge instruments limit involvement of surrounding tissue during delicate membrane dissection, thanks to shorter membrane attraction distances and reduced "sphere of influence". In addition, the

Table 1: Baseline characteristics.

	25-gauge PPV	27-gauge PPV	p value
Number of patients	37	37	
Age, mean ± SD (years)	63.1 ± 12.5	63.9 ± 13.5	0.8
Male sex, n (%)	24 (64%)	26 (70%)	0.6
Right eye, n (%)	18 (49%)	23 (62%)	0.2
Phakic, n (%)	19 (51%)	20 (54%)	0.8
Macula on, n (%)	17 (46%)	17 (46%)	1
Number of breaks, mean ± SD	2.2 ± 1.2	2.4 ± 1.5	0.6
Number of inferior breaks, mean ± SD	1.01 ± 1	1.12 ± 0.91	0.8
Number of detached quadrants, mean ± SD	2.3 ± 0.6	2.2 ± 0.5	0.4
PVR B, n (%)	3 (8%)	3 (8%)	1
PVR C, n (%)	1 (3%)	1 (3%)	1
BCVA, mean ± SD, logMAR	1.24 ± 1.04	1.21 ± 1.04	0.9

SD: standard deviation; BCVA: best-corrected visual acuity; logMAR: logarithm of the minimum angle of resolution; n: number; PVR: proliferative vitreoretinopathy.

Table 2: Outcomes.

	25-gauge PPV	27-gauge PPV	p value
N	37	37	
Surgical time, mean ± SD (minutes)	90.7 ± 29.6	86.1 ± 30.1	0.5
Anatomical success at month 6, n (%)	37 (100%)	37 (100%)	1
Anatomical success at month 6 after a single operation, n (%)	34 (92%)	33 (89%)	0.7
BCVA change at month 6, mean ± SD, logMAR	−0.71 ± 0.96	−0.67 ± 1.01	0.9
C3F8 gas tamponade, n (%)	30 (81%)	28 (76%)	0.6
Silicone oil tamponade, n (%)	7 (19%)	9 (24%)	0.6
Sutured sclerotomies, n (%)	11 (29%)	3 (8%)	0.017
Hypotony (IOP < 10 mmHg), n (%)	2 (5%)	0 (0%)	0.5
Severe IOP increase (>30 mmHg), n (%)	5 (14%)	4 (11%)	0.7

SD: standard deviation; BCVA: best-corrected visual acuity; C3F8: perfluoropropane; IOP: intraocular pressure; logMAR: logarithm of the minimum angle of resolution; n: number; PPV: pars plana vitrectomy.

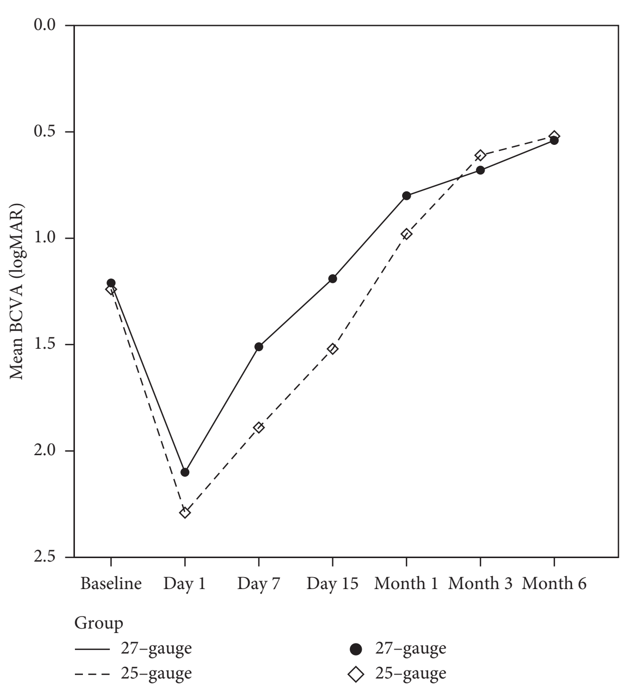

Figure 1: Best-corrected visual acuity changes.

27-gauge vitrectomy probe used in this series features a port placed 0.2 mm from the tip. Having a port so close to the edge of the probe allows greater precision and fewer tractional manoeuvres [20]. In our comparative study, we recorded no cases of iatrogenic tears in either group, and both 27-gauge and 25-gauge instrumentation were adequate in obtaining precise dissection also in the cases complicated by PVR. An adequate membrane peeling was achieved with both 25-gauge and 27-gauge forceps. It is important to note that, with its smaller diameter, the 27-gauge cutter can more easily be placed in the space between the retina and the PVR membrane, which is helpful in membrane dissection [21].

Operation efficiency is one of the major theoretical concerns regarding 27-gauge instrumentation. The inner lumen radius of a 27-gauge probe is reduced by approximately 20% when compared to a 25-gauge probe. According to the Hagen-Poiseuille law, this should theoretically result in a decrease in the flow rate by approximately 60%. However, dual pneumatically operated vitrectomy probes with ultrahigh cut rates (7500 cpm) can maintain an efficient vitreous flow rate [21]. High cut rate lowers vitreous viscosity, resulting in reduced resistance to flow. Moreover, the 27-gauge probe has excellent fluidics, and it is very effective in shaving vitreous from areas of detached retina. For these reasons, the reduced diameter of the 27-gauge instrumentation does not significantly prolong the operating times, although the posterior vitreous detachment inducement is more laborious with 27-gauge instrumentation due to lower suction capacity. In our study, we recorded a 5-minute difference favouring the 27-gauge group. No statistically significant difference in operating times was found in other comparative studies [9–12].

The decreased diameter of the instruments also leads to undesired flexibility of instrumentation and difficulty with access to the far peripheral vitreous. Such flexibility may theoretically limit the extent of peripheral vitrectomy and may permit anterior vitreous to contract leading to postoperative retinal breaks. Similar to previous reports, our study found 27-gauge instrumentation to be of adequate stiffness to complete all surgical manoeuvres requested by RRD repair with similar rigidity and functionality to 25-gauge instrumentation [9–12].

Improved wound construction and integrity has been cited as a primary advantage for use of 27-gauge over 25-gauge systems. Our results support this presumption. In our comparative study, 11 eyes in the 25-gauge group required suturing of sclerotomies compared to 3 eyes in the 27-gauge group ($p = 0.017$). Two cases in the 25-gauge group showed transient postoperative hypotony on day 1, while no cases of hypotony were recorded in the 27-gauge group.

In our study, we utilized two 27-gauge accesses for surgical instrumentation and one 25-gauge access for chandelier illuminator. This approach allows a complete surgical procedure without the need of assistance. This procedure has been previously reported in a 25-gauge versus 27-gauge comparative study for RRD [10]. However, it must be taken into account that this may limit the significance of certain comparisons, such as IOP outcomes and hypotony rates. Moreover, the results we observed using a 25-gauge chandelier may not be directly generalized and compared to procedures using a 3-port PPV with a light pipe.

There are limitations to our study that should be considered, such as the small number of eyes and the lack of randomization. However, the present study has several strengths, including its prospective design, the propensity score matching method, and the standardized, single-surgeon procedure. It is known that propensity score matching has some weakness. In particular, this approach cannot reach the level of evidence of randomized, controlled, masked clinical trials, mostly due to the effect of hidden bias due to dormant, unobserved confounders. Differently from randomization, a propensity score method can only ensure balance in measured, not unmeasured, covariables. Nevertheless, it is worthwhile to mention that this is the largest prospective comparative study regarding 27-gauge PPV in RRD and the two studied groups are well balanced and comparable. Our results show that 27-gauge PPV seems to be as safe and effective as 25-gauge PPV in RRD surgery. The primary success rate (single-surgery) and final anatomical success at month 6 showed no statistically significant difference between the 2 groups. No severe intraoperative complications were observed and, overall, postoperative complications were limited in both groups.

For these reasons, we believe that 27-gauge PPV, combined with a wide-angle viewing system and precise intraoperative localization and treatment of retinal breaks, provides excellent results as 25-gauge PPV, and therefore, it represents a valid treatment option for RRD. Further larger and randomized studies are required in order to definitely state if 27-gauge PPV is as safe and effective as 25-gauge PPV for RRD.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki.

Conflicts of Interest

PL serves as a consultant for the following companies: Alcon, Alimera, Allergan, Bausch & Lomb, Bayer, Boehringer, CenterVue, Genentech, Lupin, Lutronic, Novartis Pharma AG, Roche, Teva, and Topcon. Other authors declare that they have no conflicts of interest.

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Hindawi
Journal of Ophthalmology
Volume 2018, Article ID 9206418, 6 pages
https://doi.org/10.1155/2018/9206418

Research Article

Peak Occurrence of Retinal Detachment following Cataract Surgery: A Systematic Review and Pooled Analysis with Internal Validation

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Received 7 July 2018; Accepted 18 October 2018; Published 22 November 2018

Guest Editor: Glenn Yiu

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Introduction. Timing of retinal detachment (RD) following cataract surgery is of importance for both diagnostic and prognostic factors. However, results on RD onset-time following cataract surgery have been conflicting. *Method*. A systematic pooled analysis of the literature regarding timing of retinal detachment following cataract surgery. Outcomes were verified against an independent dataset. *Results*. Twenty-one studies, reporting on rates of RD in 3,352,094 eyes of 2,458,561 patients, met our inclusion criteria and were included in the analysis. The mean pooled time to RD following surgery was 23.12 months (95% CI: 17.79–28.45 months) with high heterogeneity between studies (I^2 = 100%, $P < 0.00001$). Meta-analytic pooling for the risk of retinal detachment revealed a risk of 1.167% (95% CI: 0.900 to 1.468, I^2 = 99.50%, $P < 0.0001$). A retrospective chart review identified 54 pseudophakic RD cases (mean age 65.5, 59.3% males). The 95% confidence interval for the mean time to RD was 3.1–6.75 years. *Conclusions*. The interval between cataract surgery and RD in a pooled analysis revealed a mean time of approximately 1.5–2.3 years. However, there was high variability between studies. Validation based on our local results showed similar yet slightly longer time frames. Timing of pseudophakic retinal detachment might direct appropriate follow-up, assisting in earlier detection.

1. Introduction

The risk of retinal detachment (RD) following cataract surgery has been estimated at 0.7%, much higher than the rate of 0.08% for rhegmatogenous RD in the general population [1]. This higher risk of RD following cataract surgery has important public health implications as the absolute number of cataract surgeries performed is steadily increasing worldwide [2].

The timing of RD following cataract surgery is of importance for both diagnostic and prognostic factors. However, results on the RD onset-time following cataract surgery have been conflicting. For example, a study from France analyzing over 2.5 million cases showed that the risk of RD increased in a nearly linear manner over time following surgery [3]. On the other hand, a 2012 study from England of 62,298 cases demonstrated that most RD cases occurred within the first 2 postoperative years [4]. To our knowledge, no systematic analysis has been published regarding the time interval between cataract surgery and RD. Therefore, the aim of this study is to perform a systemic literature review combined with pooled analysis on the temporal occurrence of RD after cataract surgery and verify the results against an independent dataset.

2. Methods

2.1. Systematic Review

2.1.1. Literature Searches Methods. A systematic search was conducted using Cochrane Library and MEDLINE, PubMed, ClinicalTrials.gov, metaRegister of Controlled Trials (http://www.controlled-trials.com), WHO International Clinical Trials Registry Platform (http://www.who.int/ictrp/search/en), and Google Scholar with the following keywords: Cataract, OR cataract surgery, OR cataract extraction, OR phacoemulsification, AND Retinal Detachment, OR, RD, and OR detachment.

2.1.2. Eligibility Criteria. The aim of this review was to identify studies which relate to effects of cataract removal on RD onset. We included studies meeting the following criteria: (1) studies examining temporal occurrence of RD after cataract surgery; (2). studies using modern method of phacoemulsification techniques; (3) written in English; (4) full publications (not an abstract or letter to the editor). Our exclusion criteria included (1) case reports and nonempirical opinion articles; (2) clear\refractive lens exchange; and (3) pediatric cases.

2.1.3. Screening and Synthesis. The review process was conducted under the guidance of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria to support reporting [5]. Two reviewers (RK and VM) independently conducted the search for relevant publications. Selected publications were then approved by a senior investigator (AA). Individual studies were graded using the Scottish Intercollegiate Guideline Network (SIGN) assessment system for individual studies as implemented for Preferred Practice Patterns by the American Academy of Ophthalmology. Supplemental Figure 1 shows the flow diagram of the inclusion process [6].

2.1.4. Statistical Analysis. Meta-analyses were performed using the Cochrane Collaboration Review Manager Software version 5.3.5. We pooled the study-specific outcome estimates and their standard errors in random-effects pooled-analyses. We assessed heterogeneity with I^2 and Cochran's Q with corresponding P values, and values less than 0.10 were considered significant for heterogeneity. When the I^2 estimate was equal to 25%, 50%, and 75%, we interpreted as indicating the presence of low, moderate, and high heterogeneity, respectively. For assessing continuous outcomes such as the time interval between CS and RD, the generic inverse variance method was used. Pooled analysis was used in order to avoid problems arising from simple pooling [7]. Graphs were created using Medcalc software version 16 (Mariakerke, Belgium). Unless otherwise specified, data are presented as mean ± standard deviation.

2.2. Retrospective Validation Analysis. As a way to independently verify the accuracy of our methods and insure that no errors were introduced during the review, extraction, or analysis processes, we compared the outcomes against separate, independent dataset. This dataset was based on patients older than 40 years of age who underwent RD surgery between January 2013 and August 2014 at the Kaplan Medical Center in Israel. We included only patients with a follow-up of at least 6 months. Routinely collected medical data included the principal diagnosis, secondary diagnoses, and procedures performed. We extracted sociodemographic variables, including age and gender. Eye characteristics, including high myopia and history of eye trauma, were collected. T-tests were conducted for continuous variables and chi-squared for categorical variables. Bivariate correlation was calculated for continuous variables (Pearson correlation). Logistic regression analysis was conducted to predict the onset of RD at 1, 3, 5, and 9 years. P values less than 0.05 were considered statistically significant. The research followed the tenets of the Declaration of Helsinki, and approval was obtained from the Kaplan Medical Center Ethics Committee.

3. Results

Following the systematic review, 21 publications met our inclusion criteria which were published from 1997 to 2017 (Supplemental Table 1). A flow diagram of the inclusion process is available in Supplemental Figure 1.

3.1. Time to the Development of Retinal Detachment. Twenty-one studies reported on the time to RD, with high variability in the reported times. Nineteen studies reported a mean value which ranged from 1.46 to 109 months; however, most (12/19) reported on a mean time which was between 12 and 40 months (1 to 3.3 years). The largest study by Daien et al. reported an interquartile range of 2.5 months to 2 years [3]. Peak occurrence was mostly reported following a few months to years; however, some studies reported that the risk remains high relative to a phakic population even at follow-up periods of over a decade. Only 7 studies reported variance metrics (standard deviations and confidence intervals) when reporting the time to the development of RD, enabling meta-analytic pooling [8–14]. The mean pooled time from surgery to RD was 23.12 months (1.9 years, 95% CI: 17.79–28.45 months) with high heterogeneity between studies (I^2 = 100%, $P < 0.00001$, Tau^2 = 50.57). These results are illustrated in Figure 1.

3.2. Risk of Retinal Detachment. Retinal detachment rates were reported in 23 publications that met our inclusion criteria (Supplemental Figure 1 and Supplemental Table 1) with a total of 3,352,094 eyes of 2,458,561 patients [3, 4, 8–26]. However, most eyes were reported by a single study by Daien et al. which reported on 1,787,021 individual cases. The weighted mean of the total follow-up period was 45 months (3.8 years, range: 3 months to 10 years, I^2 = 96%). Meta-analytic pooling for the risk of retinal detachment revealed a risk of 1.167% (95% confidence interval (CI):

Study or subgroup	Months	SE	Weight (%)	Months IV, random, 95% CI
Laube et al.	21.57	0.7056	14.5	21.57 [20.19, 22.95]
Lin et al.	38.28	0.2354	14.6	38.28 [37.82, 38.74]
Quek et al.	15.7	2.0919	13.5	15.70 [11.60, 19.80]
Ripandelli et al.	3	1.5306	14.0	3.00 [0.00, 6.00]
Sheu (2007) et al.	31	0.1915	14.6	31.00 [30.62, 31.38]
Sheu (2010) et al.	40.6	0.1377	14.6	40.60 [40.33, 40.87]
Tuft (2006) et al.	9.8	1.3	14.2	9.80 [7.25, 12.35]
Total (95% CI)			100.0	23.12 [17.79, 28.45]

Heterogeneity: $\tau^2 = 50.57$; $\chi^2 = 3204.94$, $df = 6$ ($P < 0.00001$); $I^2 = 100\%$
Test for overall effect: $Z = 8.50$ ($P < 0.00001$)

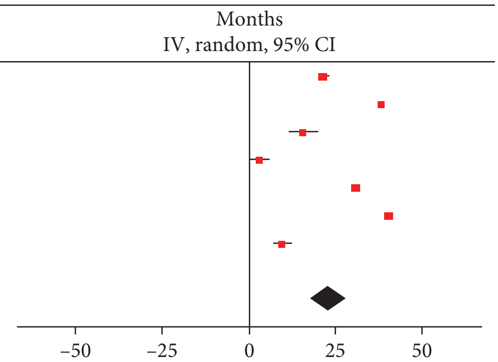

Figure 1: Forest plot for the time to retinal detachment. Size of the squares is proportional to the number of cases in the study. Error bars represent 95% confidence interval (95% CI). The diamond shape represents the pooled estimate. The mean pooled time from surgery to RD was 23.12 months (1.9 years, 95% CI: 17.79–28.45 months) with high heterogeneity between studies ($I^2 = 100\%$, $P < 0.00001$, $\mathrm{Tau}^2 = 50.57$).

0.900 to 1.468, $I^2 = 99.50\%$, $P < 0.0001$, 95% CI for $I^2 = 99.43$ to 99.55) as illustrated in Figure 2.

To test for the specificity of our results, we repeated the analyses excluding the large study by Daien et al. [3]. Results remained similar to a risk of retinal detachment of 1.183% (95% CI: 0.898 to 1.507, $I^2 = 99.07\%$, $P < 0.0001$, 95% CI for $I^2 = 98.91$ to 99.20).

Several studies reported on the age of patients (Supplemental Table 1). However, only three studies reported on the individual ages in the group which developed RD compared with those who did not. In all three studies, it appears that as age increases, the time to RD becomes shorter (illustrated in Supplemental Figure 2). However, these represent a small sample size, too small to enable statistical analyses.

3.3. Validation Analysis. Out of 139 RD cases, we included in the analyses 54 cases that were pseudophakic. We had available data on 34 patients regarding the time interval to RD. Clinical characteristics of the study population is summarized in Table 1. Of all pseudophakic RDs analyzed in this study, 25% occurred within 0.7 years after surgery, 50% within 3.1 years, 75% within 6.8 years, and 90% within 14 years. The 95% confidence interval for the mean time interval between cataract surgery and RD was 3.1–6.75 years. No relations were found between age ($r = -0.03$, $P = 0.86$, Pearson correlation), gender ($P = 0.30$, T-test) or retinal surgery anatomical success ($p = 0.75$, T-test), and the interval time from cataract surgery to RD. Logistic regression analysis failed to predict timing of RD based on clinical parameters (age, gender, and complicated cataract surgery).

4. Discussion

In this study, we used a systematic review combined with pooled analysis to assess the mean time interval after cataract surgery during which RD typically occurs. The pooled analysis revealed a mean time of approximately 1.5–2.3 years. Our retrospective validation analysis showed slightly longer time frames of about 4 years.

Cataract surgery is an independent risk factor for RD due to postsurgical anatomical and biochemical alterations in the vitreous. Anatomically, following the removal of the native lens, there are changes in the vitreous volume possibly affecting its mobility [24]. In addition, critical biochemical changes including differences in proteome, viscosity, and macromolecules in the vitreous humour were found and may lead to a posterior vitreous detachment (PVD), a known risk factor for RD [27].

Most studies in our review report decreasing rates of RD over time with a peak at a few months or years. Our results appear to support this notion considering the large range of interval periods from cataract surgery to RD (0.5–20 years with a mean of 4.9 years). Our local results indicate that a long follow-up is needed, as we did not find any clinical parameter to predict RD timing. This supports the reports by Hermann et al. who claimed that RD following cataract surgery is well underestimated and that follow-up of 8 years would include only 84.5% of all pseudophakic RD cases [24].

However, such a long follow-up may be difficult to adhere to. Potamitis et al. found that the frequency of nonattendance at outpatient ophthalmology clinics is about 10% of appointments and that roughly 18% of these were due to inattention to the date of the scheduled meeting [28]. Timing of pseudophakic RD onset is important for diagnostic and prognostic factors. It can direct precise period guidelines for follow-up or for scheduled reaching-out to patients regarding RD's signs and symptoms. In addition, locating the time period where patients are at the highest risk for RD may assist in detecting retinal break which may lead to earlier intervention. As technology emerges, the use of automatic alerts and reminders to notify clinicians and patients about appointments, in the form of text messages or emails, might improve attendance rates for appointments [29].

To note, all of the articles discussed in this study display the same trend—there is an increased risk of RD after cataract surgery in comparison to normal population; however, heterogeneity is seen between the studies in our analysis regarding the mean time interval between cataract surgery and RD and the exact cumulative risk for RD. This might be due to different populations (including high risk

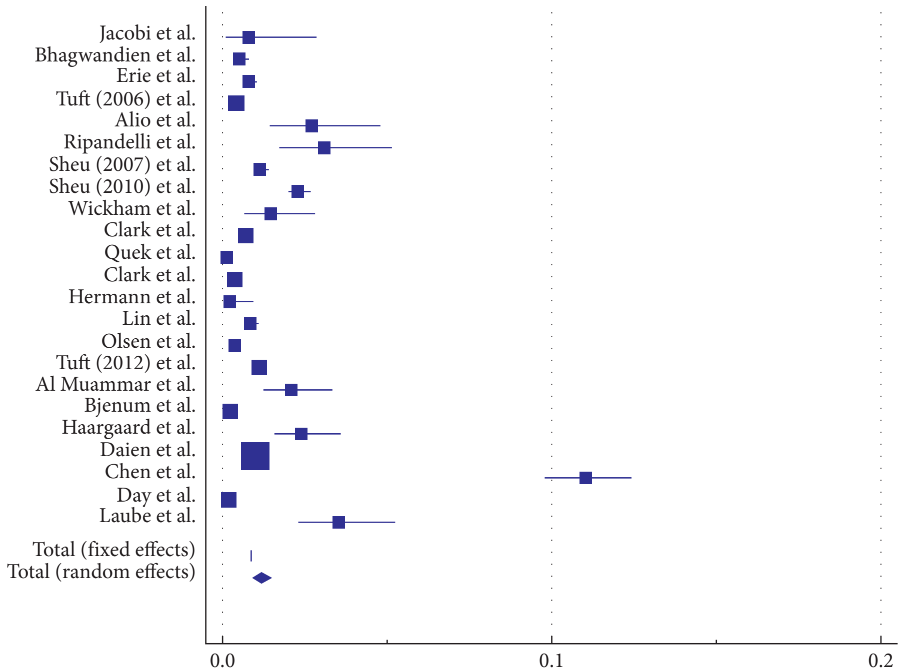

Figure 2: Forest plot for the risk of retinal detachment. Squares represent the proportion of patients who developed retinal detachment following cataract surgery at last available follow-up. Size of the squares is proportional to the number of cases in the study. Error bars represent 95% confidence interval (95% CI). The diamond shape represents the pooled estimate. The random-effect pooled estimate was 1.167% (95% CI: 0.900 to 1.468). Heterogeneity was significant (I^2 = 99.50%, $P < 0.0001$, 95% CI for I^2 = 99.43 to 99.55).

Table 1: Baseline characteristics and surgical procedures performed.

Variable	All patients (n = 54)
Mean age (years)	65.5
≥50	88.9%
<50	11.1%
Gender	
Male	59.3%
Female	40.7%
Symptoms duration	
≤1 weeks	58.9%
>1 weeks	41.1%
Trauma	11.1%
Complicated cataract surgery	25.9%
Retinal characteristics	
Macula	
On	38.5%
Off	61.5%
Inferior tears	18.5%
Lattice degeneration	7.4%
PVR	11.1%
Surgical procedure	
PR	35.2%
PPV	63%
SB	1.8%

Abbreviations: PVR, proliferative viteroretinopathy; PR, pneumatic retinopexy; PPV, pars plana vitrectomy; SB, scleral buckling.

populations) of patients as well as different surgical techniques, the year during which the procedure was performed, and the mean period of follow-up. When assessing high risk populations separately (high myopia and intraoperative complications), RD occurred earlier. Day et al. reported that pseudophakic RD occurred on average 44 days following posterior capsular rupture [22]. In addition, Alio et al. reported that almost 1% and 2% of high myopic patients will exhibit RD 6 months and 12 months following cataract surgery with posterior capsular tear, respectively [16]. Furthermore, the risk for RD tends to be higher among younger patients, with the risk reaching 3.64% at 4 years after cataract surgery among patients 40–54 years old, as reported by Daien et al. [3] Laube et al. reported an overall cumulative incidence of 3.55% among patients younger than 61 years old, at a mean duration of 3.6 years from surgery.

This study has several limitations. First, it includes many studies that differ from each other by the year of publication, the type of population included, and the mean time of follow-up. The range of timing to RD reflects this heterogeneity. Second, one of the studies we included contains a significantly larger population. In order to deal with that limitation, we analyzed the data twice, with this study and without it. Third, publications may be intrinsically biased to report success rather than failure, a phenomenon known as publication bias; therefore, the risks of developing RD after cataract surgery should be considered underestimated in this review.

To conclude, the time interval between cataract surgery and RD in a pooled analysis revealed a mean time of approximately 1.5–2.3 years. There was a high variability between the studies; however, most of them reported a mean time that ranged from 12 to 40 months. Validation based on our local results showed similar yet slightly longer time frames. Timing of pseudophakic retinal detachment might direct appropriate follow-up, assisting in earlier detection.

Data Availability

The pooled analysis data used to support the findings of this study are included within the supplementary information file. The retrospective data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Supplementary Materials

Supplemental Table 1: studies included in the analysis. Supplemental Figure 1: flow diagram of the inclusion process. Supplemental Figure 2: relationship between age of patients which developed RD and time to RD. (*Supplementary Materials*)

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Hindawi
Journal of Ophthalmology
Volume 2018, Article ID 8606494, 7 pages
https://doi.org/10.1155/2018/8606494

Review Article

Complications Associated with the Use of Expandable Gases in Vitrectomy

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Received 6 July 2018; Revised 8 October 2018; Accepted 5 November 2018; Published 18 November 2018

Guest Editor: Glenn Yiu

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Intraocular gases have been used in vitreoretinal surgery for over 40 years. The aim of this study was to review the complications related to the use of expandable gases in vitrectomy and their management. A PubMed, Cochrane Library, and Embase search was conducted using the terms "intraocular gas" and "vitrectomy for retinal detachment." Of the articles retrieved by this method, all publications in English and abstracts of non-English publications were reviewed. Intraocular pressure elevation was reported in up to 58.9% patients after vitrectomy with expandable gas administration for retinal detachment. Vitreoretinal surgery is known to induce cataract development. With that, cataract progression is associated with lens exposure to intraocular gas, the duration of such exposure, patient's age, and the magnitude of vitreous removal. With intraocular gas, the posterior surface of the lens becomes a strongly refractive factor, resulting in high myopia and temporary vision impairment. Other complications related to the use of expandable gases include anterior chamber and subconjunctival gas displacement. Single reports on subretinal and cranial gas migration were published. In vitrectomy for uncomplicated retinal detachments, attempts to shift from expandable gases towards air are observed. Nevertheless, gas tamponade remains a reasonable choice for patients suffering from retinal detachment.

1. Introduction

Intraocular gases are one of the most useful adjuncts in vitreoretinal surgery and have been used as a substitute for air for over 40 years [1]. Due to their lower water solubility than nitrogen, pure sulfur hexafluoride (SF_6), hexafluoroethane (C_2F_6), and perfluoropropane (C_3F_8) will expand when injected into the eye. Their surface tensions prevent fluid movement into retinal breaks, supporting physiological removal of fluid from the retinal space and allowing chorioretinal adhesions. A recent study revealed that intraocular gases have been applied regularly in the years of 1998–2013 and use of C_2F_6 has increased compared to C_3F_8 [2]. With that, pars plana vitrectomy is becoming the procedure of choice for rhegmatogenous retinal detachment (RRD) [2].

The aim of this study was to review the complications related to application of expandible gases in vitrectomy and possible alternatives.

2. Methods

PubMed, the Cochrane Library, and Embase were the main resources used to search the medical literature search. An extensive search was performed to identify the use and complications of intraocular gases in retinal detachment surgery as reported up to May 31, 2018. The following keywords were used in various combinations: *retinal detachment*, *vitrectomy*, *intraocular gas*, *sulfur hexafluoride*, *SF_6*, *perfluoromethane*, *CF_4*, *perfluoroethane*, *hexafluoroethane*, *C_2F_6*, *perfluoropropane*, *octafluoropropane*, *C_3F_8*, and *complications*. The reference lists of identified publications were also considered potential sources of relevant articles. Studies were critically reviewed to create an overview and guidance for further search. Only articles having English-language abstracts were included. No attempts to discover unpublished data were made. In addition to the search, selected chapters from relevant textbooks were included if necessary.

3. Results

The search revealed 1980 records, and after excluding duplicates and studies without English abstracts, 1369 records were screened. We identified 60 publications that evaluated the use of intraocular gases for retinal detachment surgery and complications related to their use. The earliest studies date the 1970s, but more than half of the publications were released after 2000. One review relevant to the topic was found in the Cochrane Database of Systematic Reviews [3]. Early research focused on gas pharmacokinetics, while more recent papers tended to evaluate the possibility of replacing expandable gases with air. The largest database study reported the outcomes of RD surgery in 3,403 eyes [4], while patient safety incidents were analyzed in 38,789 vitreoretinal procedures [5].

4. Gases Used in Retinal Detachment Surgery

The ideal gas for vitreoretinal surgery should be nontoxic, inert, insoluble in the aqueous humor, and have a lower water solubility than nitrogen [6]. SF_6 and perfluorinated short-chain carbon compounds are used (C_2F_6 and C_3F_8), and when injected into the eye, they undergo three phases before resorption: expansion, equilibration, and dissolution [7, 8]. First, the intraocular gas volume rises as the nitrogen diffusion rate into the bubble is greater than the dissolution of the gas into the surrounding tissue fluid compartment. Second, the concentration of nitrogen in the bubble is equilibrated with the bloodstream, and a small amount of expandable gas diffuses out of the eye. Finally, when the partial pressure of all gases in the bubble equals that in the fluid compartment, the dissolution begins [8]. The water solubility decreases as the carbon chain is elongated. For example, a 0.4 cc gas bubble in rabbit models disappears on average in 6, 16, and 28 days for CF_4, C_2F_6, and C_3F_8, respectively [9]. The expandable gases' expansive properties may be diminished or eliminated when diluted with air, subsequently increasing the outward diffusion [10]. The gas concentration and its half-life are linearly correlated [11].

Clinically, the longevity of a gas tamponade may differ from a theoretical model. The gas bubble duration is greater in 20-gauge vitrectomy than in microincision vitrectomy surgery [12, 13]. Such results are associated with insufficient tightness in any unsutured 23-gauge sclerotomy, causing early postoperative microleakage. The half-life of intraocular gases is longer in phakic eyes than in pseudophakic/aphakic eyes, presumably due to increased convection in the vitreous cavity of pseudophakic/aphakic eyes, which can accelerate the absorption rate [7, 14, 15]. With that, longer gas duration is correlated with an increased axial length, vitreous presence, lower aqueous turnover, and blood flow [8, 14, 16]. A survey of vitreoretinal surgeons reported that the clinical longevity of a gas bubble after a complete air-gas exchange is 13–24 days for SF_6, 28–44 days for C_2F_6, and 59–79 days for C_3F_8 [14].

5. Complications Related to the Use of Intraocular Gases

5.1. Gas Migration. Anterior chamber (AC) migration of intravitreal gas is a potential complication, which might occur even in phakic eyes with no significant zonular dehiscence or phacodonesis [17, 18]. Intraoperative gas migration into the AC hampers visualization of the posterior segment, and careful insertion of the tamponade agent without overpressurizing the globe is recommended to prevent this complication. To remove the gas from the AC and prevent further gas prolapse, it might be necessary to insert an ophthalmic viscoelastic device (OVD). In some cases, the OVD might be left inside the eye at the conclusion of surgery if migration still occurs; however, such approach necessitates careful IOP control and postoperative administration of hypotensive agents. Long-term presence of gas bubbles in the AC results in corneal edema and bullous keratopathy [19]. The gas is not toxic to the endothelium itself; however, contact between the gas and corneal endothelium results in decreased endothelial cell nutrition [20]. With that, pars plana vitrectomy itself results in a mild decrease in endothelial cell count [21]. Gas in the AC is usually managed by dilating the pupil and placing the patient face down, to allow the bubbles return to the vitreous compartment, so that the endothelium is bathed by aqueous [22].

Subconjunctival gas migration is another potential complication, particularly in microincision vitreous surgery. Gas displacement might occur intraoperatively due to trocar-associated leakage and postoperatively as a result of inadequate sclerotomy closure. In long-term, gas leakage can result in reduction of intraocular gas volume and retinal tamponade, thus influencing the retinal reattachment rate. However, in most of the cases of minor leakage no treatment is required.

Subretinal gas migration is possible particularly in eyes with optic nerve colobomas or large optic pit [23]. Imperfection in tissue overlying cavitary optic disc, faulty interconnections between the vitreous cavity, subarachnoid, and subretinal spaces, and pressure variations of cerebrospinal fluid play a critical role in subretinal gas displacement. Case reports on cranial migration of intraocular gas in the early postoperative period were published [24, 25]. Subsequently, the patients developed nausea, vomiting, and mental status changes. No surgical intervention was deemed necessary, and short-interval clinical follow-up and serial computed tomography scans were recommended. The intracranial gas gradually resolved spontaneously and so did the mental status changes; however, the vision was lost due to altered tamponade properties.

5.2. Raised Intraocular Pressure (IOP). IOP increase in eyes with intraocular tamponade is a common postoperative complication reported in up to 58.9% of eyes [26, 27].

Elevated IOP after vitrectomy may cause optic nerve damage, retinal ischemia, and subsequent visual loss. The mechanism can be open angle, closed angle, or both. In open-angle mechanism, IOP elevation is due to intraocular gas expansion. Closed-angle cases are less common but are usually a result of anterior displacement of the iris-lens diaphragm and iridocorneal apposition with or without pupillary block.

Studies reporting the incidence of IOP elevation after vitrectomy with gas tamponade are presented in Table 1. Expandable gases are supplied with different concentrations ranging from 20% to 100%, in single-use or multiple-use systems and in low-pressure or high-pressure containers with reducers. In practice, the final concentration used during vitrectomy is at the surgeon's discretion [14]. Interestingly, vitreoretinal surgeons commonly admit to having problems with incorrect gas concentration, and postsurgical IOP elevation is associated with high gas concentrations [35]. Other risk factors include advanced patient age and concomitant circumferential scleral buckling [28, 32]. In older patients, increased risk of IOP elevation is related to decreased ocular elasticity and poorer aqueous outflow, while circumferential scleral buckles decrease outflow by elevating the episcleral venous pressure [32, 36]. The incidence of hypertony is also higher in 20-gauge vitrectomy compared to transconjunctival sutureless vitrectomy, as nonsutured sclerotomies allow a free passage of air/gas if IOP is elevated [37, 38].

Chen noted that, in the majority of cases, IOP elevation is transient with the highest mean values 2–4 hours postoperatively and lasts for up to 1 week after surgery [33]. Elevated IOP potentially can be more dangerous in eyes with preexisting optic nerve damage, i.e., in glaucoma or atherosclerosis-related ischemia. Mittra et al. suggested prophylactic use of antihypertensive topical medication in patients with long-lasting gas tamponade, as in their studies they were necessary to prevent IOP elevation [34, 39]. It might be questioned whether prophylactic treatment should be recommended in all cases. We recommend vitreoretinal surgeons to benchmark their complication rate and adjust their surgical techniques and postoperative regimen.

When faced with high IOP due to an enlarging gas bubble, topical antihypertensive and systemic medications are recommended. Intravenous mannitol is known to work suboptimally in vitrectomized eyes, and several agents might be required to lower IOP. In some cases, it might be necessary to tap the gas in the outpatient clinic or operating room [40].

5.3. Cataract Development and Patient Positioning. Cataract is a common complication of vitreoretinal surgery, which develops due to inhibited diffusion of nutrients impeding proper lens metabolism [10]. Exposure to intraocular gases additionally increases retrolental oxygen levels, resulting in development of lens opacities. The severity of cataract progression correlates with the longevity of intraocular tamponade [41]. Cataracts that develop following expandable gas administration manifest as feathery formations, posterior capsule opacities, or vacuoles that are more intense in the superior part of the lens. Singh and associates noted that 18.8% of patients with intraocular gas tamponade develop cataract within three months after surgery [12]. Jackson et al. found that 51.8% of phakic patients after vitrectomy with different gas tamponade agents have subsequent phacoemulsification cataract surgery in the following 6 months [4]. Importantly, extended vitrectomy with surgical posterior vitreous detachment and anterior vitreous removal additionally increases the risk of cataract development [42]. Thompson et al. reported a more pronounced advancement in nuclear sclerosis in older age groups [43]. Postoperatively, the first symptom of nuclear sclerosis might be a myopic shift in refraction [44].

In order to decrease the contact between the gas bubble and the lens, patients might be instructed to avoid supine positioning [10]. Prone positioning might be indicated to support hole closure, as most retinal breaks develop between the posterior vitreous base and the equator [45]. With that, face-down positioning prevents forward movement of the lens-iris diaphragm caused by anterior pressure of the gas bubble, particularly in cases of floppy or atrophic iris [46–49]. Interestingly, in a study by Otsuka et al., prone position was maintained only on the day of surgery, followed by supine positioning for 7 days, and resulted in similar outcomes compared to strict prone positioning [45]. Nevertheless, it might be concluded that in general, patients with intraocular expandible gas should avoid supine positioning. Cataract development is associated with the duration of lens exposure to gas, patient's age, and the magnitude of vitreous removal.

5.4. Other Complications. The presence of intraocular gases results in light scattering on the interface between the gas bubble and adjacent intraocular fluid [10, 42]. Due to the high difference in refractive indexes between the gas and the lens, the posterior surface of the lens becomes a strongly refractive factor. Intraocular gases induce high myopia up to 50 D, which progressively diminishes as the size of the bubble decreases [50]. Patients should be informed about the reasons for vision impairment after intraocular gas administration, and it should be taken into consideration when establishing the treatment plan in monocular individuals. Variations in atmospheric pressure affect the total volume of the gas bubble. Thus, safety of patients with intraocular gas is endangered by air travel, particularly in eyes without a scleral buckle [51, 52].

Another potential complication of vitreoretinal surgery is hypotony. Although the incidence of hypotony is significantly lower in eyes with air/gas tamponade than in cases with no tamponade [53], it was reported after 31% of vitrectomies with C_3F_8 applied [54]. In most cases hypotony recovers without persistent damage; however, it does impose potential risks, i.e., increased reoperation rate [53].

In experimental studies, Doi and associates noted thinning or disappearance of the outer plexiform layer of rabbits' superior retina after intravitreal administration of 0.4 ml·C_3F_8 [55]. This finding was presumably associated

Table 1: The incidence of raised intraocular pressure after vitrectomy with gas tamponade.

Author	Incidence of IOP elevation (%)	Definition of IOP elevation	Type of surgical intervention	Gas	Risk factors for IOP elevation
Abrams et al. [28]	45	≥30 mmHg in the early postoperative period	PPV with SF_6 to reform soft eyes	SF_6 20–100%	Eyes with postoperative fibrinous anterior chamber exudates, 100% gas concentration
Chang et al. [26]	58.9	>22 mmHg within the first postoperative week	PPV for complicated retinal detachment	C_2F_6–C_3F_8 in various concentrations	N/A
The Silicone Study Group [29]	8.7	≥30 mmHg at any postoperative visit	PPV in eyes with proliferative vitreoretinopathy and prior vitrectomy	C_3F_8 14%	N/A
The Silicone Study Group [30]	6.1	≥30 mmHg at any postoperative visit	PPV in eyes with proliferative vitreoretinopathy and prior vitrectomy	SF_6 20%	N/A
Wong et al. [31]	21.7	>30 mmHg on postoperative Day-1	PPV with or without phacoemulsification cataract surgery	C_3F_8 16%	N/A
Wong et al. [31]	20.4	>30 mmHg on postoperative Day-1	PPV with or without phacoemulsification cataract surgery	SF_6 30%	N/A
Chen and Thompson [32]	43	>25 mmHg in early postoperative period	PPV with or without scleral buckling	SF_6 10–30% or C_3F_8 5%–35%	Increasing patient age; expansile gas concentrations; use of C_3F_8; circumferential scleral buckles
Chen [33]	52	>30 mmHg within 1 week after surgery	PPV for macular hole surgery	C_3F_8 14%	N/A
Mittra et al. [34]	52.4 (>25 mmHg) 28.6 (>30 mmHg)	Elevation 4–6 hours postoperatively	PPV	SF_6 18%–20% or C_3F_8 12%–16%	N/A
Wong et al. [5]	0.5–1.3	N/A	Vitreoretinal surgery	N/A	N/A

Abbreviations: IOP, intraocular pressure; PPV, pars plana vitrectomy. The study by Wong et al. [5] presenting the incidence of IOP elevation in all vitreoretinal procedures is presented for comparative purposes.

with mechanical damage of the retina related to the contact with the expansive gases, rather than the toxicity of the vitreous substitute. In vivo studies did not confirm the influence of gas tamponade on retinal layer segmentation; however, reduction in the ganglion cell and outer retinal layers was found in eyes with long-term silicone oil tamponade [56].

6. Alternatives to Expandable Gases in Retinal Detachment Surgery

In addition to possible complications associated with long-acting gases, other disadvantages include their cost, the time, and workload required to acquire and store them and additional surgical time for dilution and administration. Several studies assessed the utility of air tamponade for eyes undergoing vitreoretinal surgery [57, 58]. A significant advantage of applying air compared to expandible gases is a shorter prone-positioning and recovery period. Tan and associates presented that patients with complete air tamponade had a similar vitrectomy success rate compared to 20% SF_6, but only in RRDs with upper quadrants involved [59]. Zhang et al. reported similar success rate RRDs with superior retinal breaks in eyes with partial and complete air tamponade [60]. In other studies, air was used exclusively for tamponade in vitrectomy for RD, resulting in the similar reattachment rate in inferior breaks as well [57, 58]. Nevertheless, the majority of primary uncomplicated RRDs remain treated with expandible gas tamponade.

As air does not provide a long-term tamponade, it cannot be considered in eyes with recurrent RDs, in primary RDs that are associated with a varying intensity of proliferative vitreoretinopathy, or growth of fibrous tissue [3]. Schwartz et al. in the Cochrane Database for Systematic Reviews revealed that only the use of perfluoropropane (C_3F_8) or silicone oil is a reasonable choice for most patients with RD associated with proliferative vitreoretinopathy [3]. With that, long-lasting gas tamponade with C_2F_6 or C_3F_8 might be recommended for RRDs with inferior breaks or with giant retinal tears [61, 62].

7. Conclusions

The use of intraocular gases can result in postoperative intraocular pressure elevation, cataract formation, gas migration, and temporary vision impairment due to the a high difference in refractive indexes between the gas and the lens. In vitrectomy for uncomplicated retinal detachments, attempts to shift from expandable gases towards air are observed. Nevertheless, gas tamponade remains a reasonable choice for patients suffering from retinal detachment.

Appendix

A. Methods for Literature Search

Literature searches of the PubMed, Embase, and Cochrane databases were conducted in May 2018; the search strategies are as follows. Specific limited update searches were conducted after May 2018.

A.1. PubMed Searches (Publication Date 1/10/11–5/31/2018). ((“retinal detachment”[MeSH]) OR (“vitrectomy”[MeSH])) AND ((“gas”[MeSH]) OR (“sulfur hexafluoride”[MeSH]) OR (“perfluoromethane”[MeSH]) OR (“perfluoroethane” [MeSH]) OR (“perfluoropropane”[MeSH]) OR (“octafluoropropane”[MeSH]) OR (“SF6”[Title/Abstract]) OR (“CF4”[Title/Abstract]) OR (“C2F6”[Title/Abstract]) OR (“C3F8”[Title/Abstract])). 803 references.

A.2. Cochrane Searches (Publication Date 1/10/11–5/31/2018). MeSH descriptor Retinal Detachment explode all trees in Cochrane Database of Systematic Reviews. 23 references.

MeSH descriptor Vitrectomy explode all trees in Cochrane Database of Systematic Reviews. 15 references.

A.3. Embase Searches (Publication Date 1/10/11–5/31/2018). ((*“retinal detachment”*/de OR *“retinal detachment”*) OR (*“vitrectomy”*/de OR *“vitrectomy”*)) AND ((*“gas”*/de OR *“gas”*) OR (*“sulfur hexafluoride”*/de OR *“sulfur hexafluoride”*) OR (*“perfluoromethane”*/de OR *“perfluoromethane”*) OR (*“perfluoroethane”*/de OR *“perfluoroethane”*) OR OR (*“perfluoropropane”*/de OR *“perfluoropropane”*) OR (*“octafluoropropane”*/de OR *“octafluoropropane”*) OR (*“SF6”*/de OR *“SF6”*) OR (*“CF4”*/de OR *“CF4”*)OR (*“C2F6”*/de OR *“C2F6”*) OR (*“C3F8”*/de OR *“C3F8”*)) 1139 references.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Hindawi
Journal of Ophthalmology
Volume 2018, Article ID 6127932, 6 pages
https://doi.org/10.1155/2018/6127932

Clinical Study

Modified Vitrectomy Technique for Phakic Rhegmatogenous Retinal Detachment with Intermediate Break

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Received 14 June 2018; Revised 6 September 2018; Accepted 1 October 2018; Published 23 October 2018

Academic Editor: Elad Moisseiev

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Purpose. To evaluate the effects of a modification of the traditional 25-gauge pars plana vitrectomy technique in the treatment of uncomplicated macula-on rhegmatogenous retinal detachment (RRD) with intermediate retinal break(s) and marked vitreous traction in the phakic eye. *Methods*. Prospective, noncomparative, and interventional case series. All consecutive phakic eyes with primary uncomplicated macula-on RRD with intermediate retinal break(s) and marked vitreous traction, with at least 1 year of postoperative follow-up, were enrolled. In all eyes, "localized 25-gauge vitrectomy" under air infusion with localized removal of the vitreous surrounding the retinal break(s), in association with laser photocoagulation and air tamponade, was performed. The primary end point was the rate of primary retinal attachment. Secondary end points were cataract progression and assessed by digital Scheimpflug lens photography (mean change of nuclear density units) and the rate of complications. *Results*. Thirty-two phakic eyes were included in the final analysis. At 12 months, the primary outcome of anatomical success was achieved in 94% of eyes. The mean nuclear density units did not change significantly at any time point during the follow-up. After localized vitrectomy, one eye developed an epiretinal membrane, and one eye developed cystoid macular edema; no other significant complications were reported. *Conclusions*. "Localized vitrectomy" has a high anatomical success rate in phakic eyes with primary uncomplicated macula-on RRD with intermediate retinal break(s) and marked vitreous traction, without causing progression of cataract.

1. Introduction

Scleral buckling (SB), primary pars plana vitrectomy (PPV), and pneumoretinopexy (PR) are the surgical procedures to treat primary rhegmatogenous retinal detachment (RRD). In the last few decades, primary PPV is the method of choice to manage RRD for several reasons including technical advances, lower postoperative inflammation, less patient discomfort, and greater familiarity of surgeons with this technique compared to the SB procedure [1–3]. The major disadvantages of primary PPV are cataract progression and iatrogenic retinal breaks [1].

The location and size of the retinal break(s) is one of the clinical features that influence the choice of treatment [1].

The scleral buckling versus primary vitrectomy in rhegmatogenous retinal detachment (SPR) study [4] included primary medium-severe RRD with intermediate breaks, described as "breaks between the equator and major vessel arcades."

In the management of RRD, the SPR study [5] suggested that the SB procedure in the phakic eyes shows a better postoperative visual acuity while the vitrectomy technique in the pseudophakic eyes shows better anatomical outcomes. However, no correlation about choice of treatment between

SB and PPV, and between visual and anatomic outcomes, according to the location of breaks was made in this study specifically.

SB is difficult to perform in cases involving an intermediate location of the break(s), and it is associated with many possible complications [6–10].

However, SB has the advantage of less risk of cataract development and substantially lower cost over PPV [1, 11].

In this study, the authors describe a new technique called "localized vitrectomy," used to treat uncomplicated macula-on primary RRD with intermediate break(s) and marked vitreous traction, in the phakic eyes. This procedure is a modification of the traditional 25-gauge PPV, consisting of a mini-invasive vitrectomy with a limited vitreous removal surrounding the retinal break(s), without core vitrectomy or shaving the vitreous base over 360°. Furthermore, the authors have evaluated the efficacy of this procedure, including visual and anatomic results, complication rate, and postoperative cataract progression.

2. Methods

In this prospective study, all consecutive phakic eyes that underwent 25-gauge PPV for primary macula-on primary RRD with intermediate break(s) and marked vitreous traction at the Ophthalmological Clinic of Catania between January 2014 and September 2016 were included. The risks and benefits of the treatment were explained to the patients, and a written consent was obtained in accordance with the Helsinki Declaration before the procedures. The Institutional Review Board/Ethics Committee approved the design of the study.

The inclusion criteria were as follows:

(1) Phakic eye
(2) Primary uncomplicated macula-on RRD including PVR grade A or B with one or more contiguous intermediate retinal break(s), defined as breaks between the equator and major vessel arcades [2], and with marked vitreous traction
(3) Presence of posterior vitreous detachment (PVD)
(4) Absent-to-moderate cataract (grade 0.0 to 2.0 in the Thompson classification) in the RRD eye and in the controlateral eye [12]
(5) Minimum follow-up of 12 months

Patients were excluded if they had secondary retinal detachment, previous ocular surgery, amblyopia, other rhegmatogenous retinal lesions, posterior retinal breaks (macular hole or between the major vessel arcades), giant breaks, or vitreous hemorrhage that required complete PPV.

Primary end point was the rate of primary retinal attachment; secondary end points were cataract progression and the rate of complications.

Two experienced vitreoretinal surgeons evaluated all primary RRD at the Ophthalmological Clinic of Catania between January 2014 and September 2016 and independently assessed and identified macula-on primary RRD with intermediate break(s) and marked vitreous traction. All cases in which surgeons differed in their clinical assessment of degree of the RRD, with inconsistence decisions, were excluded.

We divided fundus drawings into 4 quadrants centered at the fovea, superotemporal (ST), superonasal (SN), inferotemporal (IT), and inferonasal (IN), respectively, and recorded the location of each break in the 4 quadrants.

As superior break, we defined a retinal break located between 9 and 3o'clock meridian, and as inferior break, a retinal break between 4 and 8o'clock meridian.

Before vitrectomy, an independent, experienced retinal specialist (M. F.) assessed the presence of PVD using a slit-lamp biomicroscopy with an external lens of 78 diopters to identify the presence of the Weiss ring and the visible posterior vitreous cortex. A second retinal specialist (A. R.) performed 10 MHz B-scan ultrasonography (Cinescan S HF, Quantel Medical, Clermont-Ferrand, France) using transverse and longitudinal scans. Only eyes with PVD confirmed by both techniques were enrolled in the study.

All patients underwent a complete ophthalmic evaluation including measurement of best-corrected visual acuity (BCVA) and intraocular pressure (IOP) and examination of the anterior segment and dilated fundus preoperatively (at baseline) and at 1 day, 1 week, and 3, 6, 9, and 12 months after surgery.

BCVA was measured using early treatment diabetic retinopathy study charts by a single well-trained and experienced ophthalmologist (M. T.). Vision results were quantified as a logarithm of the minimum angle of resolution (logMAR).

IOP was measured by the Goldmann applanation tonometry. Hypotony was defined as an IOP of 5 mmHg or less.

In all patients, the lens status evaluation was performed with digital Scheimpflug lens photography at the baseline and at 3, 6, and 12 months after surgery. The nuclear density was assessed in the vitrectomized eye (study group) and in the fellow eye (control group). Lens images were obtained and analyzed by using a Nidek EAS-1000 anterior segment analysis system (Nidek, Gamagori, Japan). All lens images were taken by the same observer (A. L.) after pupillary dilation and at the same settings, as previously described by Sawa et al. [13] and Vivino et al. [14]. The opacification value of the nuclear region was expressed in nuclear density units (NDUs).

All preoperative, intraoperative, and postoperative data including patient demographics (age and sex) and postoperative complications were recorded in a database. The incidence, timing, and causes of retinal redetachment were also registered.

2.1. Surgical Technique. All patients underwent 3-port 25-gauge vitrectomy with a valved trocar system performed by the same surgeon (T. A.) under local sub-Tenon's anesthesia (using 10 ml of a 50 : 50 mixture of 2% lidocaine and 0.5% bupivacaine with 150 IU hyaluronidase). Surgical procedures were performed using the Stellaris PC under a Resight 700 noncontact panoramic viewing system

(Carl Zeiss Meditec). The sclerotomy was placed 4 mm posterior to the limbus. With closed infusion, the retinal break(s) were localized, the eye was rotated in order to position the region of the retinal break as high as possible, and air infusion was started with a pressure of 30–35 mmHg. Localized removal of the vitreous surrounding the retinal break(s) was performed, and a complete release of the vitreoretinal adhesion surrounding the retinal break(s) was obtained. Finally, the subretinal fluid was drained with a needle through the retinal break. Neither core vitrectomy nor shaving of the vitreous base was performed.

After complete retinal attachment was achieved, endolaser photocoagulation was applied around the retinal break(s). Tamponade was performed with filtered air. Transconjunctival sutures were placed only in two eyes, in which leakage at the sclerotomy sites was observed. All patients were asked to maintain a specific head position, according to the location of the retinal break, for 3 days after surgery. In particular, patients with inferior break(s) were instructed to maintain a face-down and lateral position, while patients with superior break to maintain upright and lateral position depending on the quadrant o'clock meridian.

2.2. Statistical Analysis. Measured Snellen visual acuity values were converted to the logMAR values for subsequent analysis. The analysis of variance (ANOVA) was used to compare the mean values of pre- and postoperative BCVA and IOP in the vitrectomized eyes (study group) and to compare the mean NDUs of the study group eyes with that of the control group eyes (fellow eyes) at baseline and at 3, 6, and 12 months after treatment. Multiple comparisons were performed using the Tukey HSD test, if the differences were significant. Student's t-test was used to compare the mean NDUs detected in the two groups. P values <0.05 were considered significant. The data were analyzed using the Statistical Packages for the Social Sciences for Windows (v.17.0; SPSS, Chicago, IL, USA).

3. Results

Of the 46 phakic consecutive eyes with uncomplicated macula-on RRD and intermediate retinal break(s) with marked vitreous traction, 11 eyes were excluded (5 eyes did not have PVD, 4 eyes had cataract more than grade 0.0–2.0, and 2 patients declined to participate), and 35 eyes addressed the inclusion criteria and were enrolled in the study. Of the these 35 eyes recruited for surgery, only 32 eyes were included in the analysis because 2 patients were lost during the follow-up period, and one patient had intraoperative vitreous hemorrhage during surgery and required conversion to standard PPV (Figure 1). Of the 32 eyes with RRD, 22 (68.7%) had superior retinal breaks and 10 (31.3%) had inferior retinal breaks. In particular, 19 eyes (59.3%) had retinal break(s) located in the ST quadrant, 7 eyes (21.8%) had break(s) in the IT quadrant, 3 eyes (9.3%) in the SN, and 3 eyes (9.3%) in the IN quadrant.

The mean (SD) age of patients was 61.5 ± 13.3 years; 18 patients (56%) were men, and 14 (44%) were women.

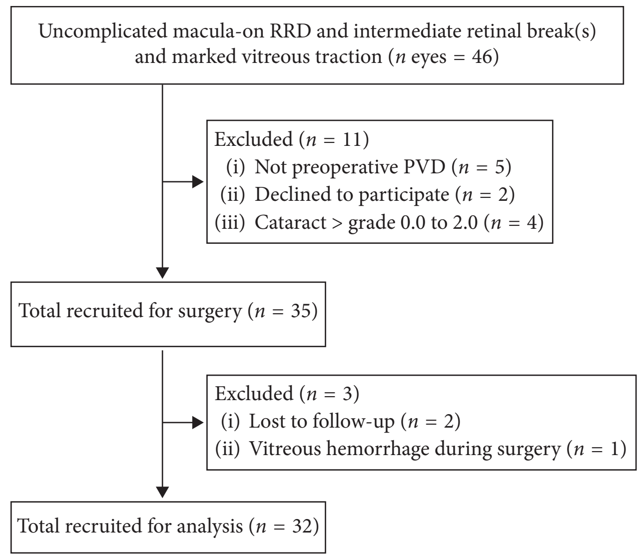

Figure 1: Flow diagram of the study (enrollment).

3.1. Primary Anatomical Success Rate. The primary anatomical success rate, defined as retinal reattachment at the final follow-up of 12 months after a single operation, was 94% (30 of 32 eyes): 95 4% of eyes with superior retinal breaks (21 of 22 eyes) and 90% of eyes with inferior retinal breaks (9 eyes of 10), respectively ($P = 0.534$). Recurrence of RRD occurred in 2 eyes (6%) during the follow-up period: one eyes with preoperative ST retinal break and one eye with preoperative IT retina break. Both occurred within 1 month after the first operation. The redetachment was attributed to development of grade C PVR in one eye and to a new peripheral retinal break in the inferior quadrant in the other eye. Both of these eyes were reoperated by 25-gauge vitrectomy and SF6 tamponade; the retinal reattachment was obtained in both eyes. Thus, the final anatomical success rate, defined as retinal attachment at the final follow-up without regard to additional procedures, was 100% (32 of 32 eyes).

3.2. Visual Acuity. ANOVA showed no change in the mean BCVA from the baseline to 12 months after surgery. The mean ± SD logMAR BCVA was 0.17 ± 0.13 logMAR, 0.17 ± 0.12 logMAR, 0.16 ± 0.12 logMAR, and 0.16 ± 0.1 logMAR, respectively, at the baseline and 3, 6, and 12 months, without significant difference (ANOVA, $P = 0.973$).

3.3. Progression of Lens Opacity. At the baseline, the mean ± SD NDU was 68 ± 12 in the study group and 69 ± 14 in the control group (t-test $P = 0.933$) (Table 1). ANOVA showed that the mean NDUs did not change significantly in either group during the follow-up (study group $P = 0.523$; control group $P = 0.725$). No difference in NDUs was found between two groups at 3, 6, and 12 months.

No intraoperative complications were observed.

No significant IOP changes were detected during the follow-up period (ANOVA, $P = 0.781$). The mean ± SD preoperative and postoperative IOP at 1 day, 1 week, and 1, 3, 6, and 12 months, were 13.6 ± 3.1 mmHg, 13.1 ± 4.5 mmHg,

Table 1: NDUs at the baseline and at 3, 6, and 12 months after surgery.

NDUs (range, 0 to 255 steps) (mean ± SD)	Vitrectomy group	Control group	P^*
Baseline	68 ± 12	69 ± 14	0.933
3 months	70 ± 12	69 ± 16	0.779
6 months	72 ± 18	71 ± 11	0.875
12 months	73 ± 15	72 ± 9	0.724

*t-test.

13.7 ± 3.2 mmHg, 14.2 ± 5.2 mmHg, 14.7 ± 4.7 mmHg, 14.4 ± 3.9 mmHg, and 14.2 ± 4.5 mmHg, respectively. No hypotony was detected in any eyes, and none of the patients had endophthalmitis after surgery.

One eye developed an epiretinal membrane (ERM) 3 months after surgery and one eye showed cystoid macular edema at 1 month-follow up examination, resolved after topical therapy. No other postoperative complications were registered.

4. Discussion

Our study showed that a "localized vitrectomy" was effective in the treatment of primary macula-on RRDs, with superior and inferior, intermediate break(s) and marked vitreous traction in the phakic eyes and did not cause significant progression of cataract.

To date, no study has evaluated the efficacy of different surgical techniques in presence of uncomplicated RRD and intermediate retinal break(s).

PR is a well-accepted alternative surgical technique to scleral buckling and vitrectomy for RRDs with one or more retinal breaks within one clock hour; however, it is contraindicated in the eyes with inferior retinal break(s) and in which breaks are held open by vitreous traction [15].

The SPR study evaluated the phakic eyes with medium-severe primary RRD and intermediate break(s) [3] and shows better functional outcomes with the SB procedure than PPV. However, SPR study analysis included primary RRD with many different preoperative variables, such as macula-on only in 42.9% of eyes, RD with multiple breaks in different quadrants, bullous RD, intermediate breaks with marked vitreous traction, and RD with unclear hole situations. Furthermore, in the SPR study, no subanalysis of postoperative outcomes was conducted to identify any relation between choice of treatment and location of break(s), in particular intermediate break(s) [3].

The surgical SB procedure to treat primary RRD is very challenging in the eyes with intermediate break(s). Despite the advantages of not increasing the risk of cataract and being less expensive than PPV, SB can cause several possible complications, such as myopic shift in refraction (68%) [6], diplopia with extraocular muscle dysfunction (3%–50%) [6–8], choroidal detachment (23%–44%) [7], subretinal hemorrhage (3%–5.1%) [8, 9], iatrogenic scleral break (2%) [10], accidental subretinal fluid drainage (5%–8%) [8, 10], retinal breaks (0.54%–4%) [8], choroidal hemorrhage (2%) [10], retinal incarceration (2.2%–3%) [8], explant exposure (6%) [10], macular pucker (2%) [6, 9], and PVR (5%–21%) [6, 9].

Moreover, breaks between the equator and major vessel arcades are commonly supported by one or more large radial sponges that need a surgical familiarity for the correct sponge placement with a potential risk of compression of the vortex veins [1].

In a previous study, Uemura and Nakao showed that, in the eyes with uncomplicated RRD caused by a posterior retinal break, both procedures SB and PPV had a similar visual recovery but the vitrectomized eyes had less severe intraoperative complications compared with SB [16].

Vitrectomy offers some advantages such as easy access to intermediate retinal breaks and greater familiarity with this technique compared with SB [1, 4]. However, PPV is known to cause cataract progression and may cause several other complications such as glaucoma (8.9%) [17], choroidal hemorrhage (0.8%) [18], diplopia/EOM dysfunction (0.5%–7%) [6, 9], cataract (70%) [9], macular pucker (9%) [7], postoperative PVR (6%–18%) [6, 7], and iatrogenic retinal breaks (6%–15.7%) [7, 19].

Our small gauge-modified vitrectomy showed a single-operation anatomical success rate of 94%, which is consistent with the rates of 74–93.9% for repair of primary RRD in other reports of conventional small-gauge vitrectomy [20–22] and did not cause significant progression of cataract.

We observed only one case with intraoperative hemorrhage requiring conversion to standard PPV and that was excluded by the analysis.

Moreover, no statistically significant difference between eyes with superior retinal break(s) and eyes with inferior retinal break(s) in terms of primary anatomical success rate ($P = 0.534$) was noted in our study. However, this topic is still controversial; in fact, despite Goto et al. [23] reported that inferior retinal breaks were significantly associated with a lower success anatomic comparing with superior retinal breaks (80% versus 98%, $P = 0.012$), the other authors [24] showed inferior breaks do not represent a risk factor for worse anatomical and functional results (96.5% versus 93.3%, respectively, in superior and inferior retinal breaks).

It is well established that vitrectomy increases lens opacity in most eyes when assessed at 6 months regardless of the caliber of the instrument [25].

In our study, no progression of nuclear sclerosis was observed through the 12 months of follow-up, and the NDUs at 12 months did not differ between the vitrectomized and fellow eyes. Our result is consistent with previous studies that found no progression of cataract in the eyes that had undergone removal of the ERM without vitrectomy [26, 27].

The mechanism underlying cataract progression after vitrectomy is not completely understood. One hypothesis is that, in the absence of vitreous gel, molecular oxygen from the retinal vasculature reaches the lens and promotes oxidative damage of the lens nucleus and nuclear sclerotic cataract [28]. According to this hypothesis, the very limited amount of vitreous removal in our modified vitrectomy, with core and vitreous base preservation, could explain the absence of progression of cataract.

Our choice to use air as tamponade was supported by findings of previous studies reporting favorable results with air tamponade in the management of RRD, with a single-operative success rate from 84.38% to 94.4% [29]. Air used as gas tamponade showed no inferior results to long-acting gas because of the adhesion between retina and retinal pigment epithelium (RPE) occurring within 24 hours. Moreover, long-acting and expansive gas could cause vitreous disturbance and increase the risks of elevated IOP, PVR, and new or missed tears [30].

Despite the recent evolution of vitreoretinal surgical techniques, the incidence of "new" retinal breaks has been reported for small-gauge PPV in up to 15.7% of eyes [19]. Although the sample number was small in our study, we found new retinal breaks in only 1 eye (3%) during the 12-month follow-up and suggests that the residual vitreous does not cause secondary vitreous traction in these eyes. Similarly, previous reports of no vitrectomizing vitreous surgery for ERM have also reported no new retinal breaks during the long follow-up [31].

In our series, ERM developed in 3% of eyes. This is a lower percentage than the 3.6–12.8% reported by others [32, 33]. The most likely explanation for the development of ERM is that the retinal pigment epithelial cells migrate to the surface of the posterior pole of the retina by diffusing into the vitreous cavity through the break or through fibrosis [33]. In our modified technique, the remaining vitreous probably prevented such diffusion into the vitreous cavity.

Furthermore, a potential advantage of our new technique of "localized vitrectomy," without core and vitreous base removing, is that it still allows intravitreal injections in the eyes experiencing the onset of neovascular age-related macular degeneration, which can be difficult to treat after previous conventional PPV. Experimental studies have shown a reduction in the intravitreal half-life of drugs in the vitrectomized eyes due to significantly faster clearance rates of the drugs after vitrectomy, which could make them less effective [34, 35], and it may require more frequent treatment regimen of anti-VEGF therapy [34, 35].

The main limitations of this study are the small number of patients enrolled and the lack of an interventional control group. Large studies should also evaluate the efficacy and rate of postoperative complications.

5. Conclusion

"Localized vitrectomy" seems to be an effective surgical procedure to treat uncomplicated macula-on primary RRD with intermediate break(s), marked vitreous traction, and PVD in the phakic eyes, achieving a high anatomical success rates without progression of cataract.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest with this submission.

Authors' Contributions

All authors listed on the title page have read the manuscript and agreed to its submission. VB, MDT, AL, TA, and MR did conception, design, statistical analysis drafting, and critical revision. RR, KN, AR, MF, TC, AK, EO, and SZ performed drafting, data acquisition, and critical revision. All authors approved the final version of the manuscript.

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Hindawi
Journal of Ophthalmology
Volume 2018, Article ID 7643174, 5 pages
https://doi.org/10.1155/2018/7643174

Research Article

Comparison of 25- and 27-Gauge Pars Plana Vitrectomy in Repairing Primary Rhegmatogenous Retinal Detachment

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Received 12 March 2018; Accepted 6 May 2018; Published 25 June 2018

Academic Editor: Ala Moshiri

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Aim. To compare the anatomic and visual outcomes of 25-gauge (25G), and 27-gauge (27G) transconjunctival sutureless pars plana vitrectomy (TSV) for the management of primary rhegmatogeneous retinal detachment (RRD). *Design*. A retrospective nonrandomized clinical trial. *Methods*. A retrospective comparative analysis of 62 consecutive eyes from 62 patients with 6 months of follow-up was performed. *Results*. Thirty-two patients underwent 25G TSV, and 30 patients underwent 27G TSV for the treatment of primary RRD. There was no significant difference in baseline demographic and preoperative ocular characteristics between the two groups. The initial and final anatomical success rates were 93.8% and 100% in 25G TSV and 96.7% and 100% in 27G TSV, respectively ($p = 1$ and $p = 1$, resp.). Preoperative best-corrected visual acuity (BCVA) (logMAR) was 0.44 ± 0.69 and 0.38 ± 0.61 for 25G and 27G TSV, respectively ($p = 0.73$). The final follow-up BCVA was 0.07 ± 0.25 and -0.02 0.17 for 25G and 27G TSV, respectively ($p = 0.16$). The final BCVA was significantly better than the preoperative BCVA in both groups ($p = 0.02$ and $p = 0.002$, resp.). Preoperative intraocular pressure (IOP) (mmHg) was 13.0 ± 3.5 in 25G TSV and 14.3 ± 2.8 in 27G TSV ($p = 0.11$). IOP did not statistically significantly change in both groups during the follow-up period ($p = 0.63$ and $p = 0.21$, resp.). *Conclusion*. The 27G TSV system is safe and useful for RRD treatment as 25G TSV.

1. Introduction

Since the transconjunctival sutureless pars plana vitrectomy (TSV) with 25-gauge (25G) and 23-gauge instrumentation was introduced, there is an accumulating trend toward TSV as the first choice for the treatment of a variety of vitreoretinal surgical indications [1–3]. The advantages of TSV including the small incision, self-sealing, decreased surgical trauma, and less postoperative inflammation provide patients better postoperative comfort, less postoperative astigmatism, and earlier visual recovery compared to the traditional 20-gauge vitrectomy system [4–8]. In 2010, Oshima et al. first reported a preliminary study regarding the safety and practicality of the 27-gauge (27G) instrument system for the vitreoretinal surgery [9]. Although the low rigidity of 27G instruments have been reported, several reports have suggested the clinical outcomes and short-term safety profile of 27G TSV for a variety of surgical indications, including rhegmatogeneous retinal detachment (RRD) [10–14]. However, there remained big concerns whether all surgeons can manage the 27G instrument especially on peripheral vitreoretinal disorders because the low instrument rigidity of 27G sometimes cause the difficulty of the operation and may impact the results especially for inexperienced surgeons.

In this study, we performed a retrospective comparative study to examine the anatomical success rates and complications of 25G and 27G TSV in the repair of primary RRD.

2. Patients and Methods

We performed retrospective analyses of the medical records of 62 consecutive eyes of 62 patients with primary uncomplicated RRD treated with 25G (group A) or 27G (group B) TSV. This study is a nonrandomized, retrospective comparative clinical trial. Our study was performed after obtaining the approval of the institutional review board in Kobe University School of Medicine and Kobe Kaisei Hospital. The procedure used conformed to the Tenets of the Declaration of Helsinki. Patients were enrolled from January 2014 through June 2015. Surgeries were performed by six surgeons. Ophthalmic residents in each hospital assisted all surgeries. Three surgeons who had experienced over 1000 vitreoretinal surgeries are thought to be experienced doctors, and the other three surgeons who had experienced less than 100 vitreoretinal surgeries are thought to be inexperienced doctors. Eyes with giant retinal tears, proliferative vitreoretinopathy, atopic dermatitis, and a history of prior surgery for RRD were excluded. The patients were followed up at least for 6 months after the surgery. The following variables were analyzed: sex, age, primary surgeon, preoperative best-corrected visual acuity (BCVA), postoperative BCVA, preoperative intraocular pressure (IOP), postoperative IOP, the primary anatomical success rate, the final anatomical success rate, the number of retinal breaks, locations of retinal breaks, the number of quadrants involved, the presence or absence of the macular detachment, the number of eyes who needed the suture for sclerotomy sites, the operative time, and the lens status.

2.1. Statistical Methods. The chi-square test and Fisher's exact probability test for dichotomous variables and unpaired t-test for continuous variables were used to compare parameters listed above between the two groups. Paired t-test was used for comparison between pre- and postoperative VA within the same group. We used the Kruskal–Wallis H-test to examine the transition of IOP in each group.

For logistic multiple regression analysis, univariate analysis was performed to establish the relationships between explanatory variables and the primary anatomic success rate, using the chi-square test, Fisher's exact probability test, and unpaired t-test. The level of statistical significance was set at $p < 0.20$. The variables found to be significant in univariate analysis were analyzed with backward logistic multiple regression analysis, using the MedCalc (MedCalc version 12.7.5.0; MedCalc Software, Mariakerke, Belgium). Statistical significance was inferred for $p < 0.05$. The Landolt decimal VA was converted to logarithmic minimum angle of resolution (logMAR) for statistical analysis.

2.2. Surgical Procedures. All surgeries were performed under sub-Tenon anesthesia consisting of approximately 4 mL of 2% lidocaine. The Constellation Vision system (Alcon Laboratories, Inc., Forth Worth, TX, USA) was used for both 25G and 27G TSV with a wide-angle noncontact viewing system (Resight®; Carl Zeiss Meditec AG, Jena, Germany). Three cannulas were created with conjunctival displacement and oblique-angled sclerotomies in the inferotemporal, superotemporal, and superonasal quadrants 3.0–4.0 mm posterior to the limbus. 27G twin chandelier illumination fibers (Eckardt TwinLight Chandelier, Dorc International, Zuidland, Netherlands) or 29G twin chandelier illumination fibers (Oshima dual, Synergetics USA, Inc.) were placed at 4.0 mm behind the limbus for wide-angle intraocular illumination. Before vitrectomy, for better visualization and shaving of peripheral vitreous, cataract extraction with phacoemulsification using the same machine and intraocular lens implantation were performed for all phakic eyes. Following the core vitrectomy, triamcinolone acetonide (MaQaid, Wakamoto Pharmaceutical, Tokyo, Japan) was injected to visualize vitreous gel during midperipheral vitrectomy. Then, the peripheral vitreous gel was shaved for 360° with scleral indentation under a wide-angle noncontact viewing system. No internal drainage retinotomies was made in the majority of cases to avoid the awareness of a scotoma but made in the most dependent or anterior part of the detached retina if necessary. Subretinal fluid was evacuated from original tears or drainage retinotomy sites and followed by a complete fluid-air exchange. All retinal detachments were reattached intraoperatively. Endolaser photocoagulation was applied to completely surround all retinal breaks and drainage retinotomy sites. At the end of surgery, all eyes were flushed with 50 mL of mix of 20% SF_6 gas to assure a complete exchange. Additional gas mixture was injected through the pars plana to adjust IOP if necessary. Any sclerotomy sites that were found to be leaking at the end of the surgery were sutured with 8-0 vicryl suture. Normal IOP was checked by tactile examination. Subconjunctival corticosteroids were injected, and antibiotic ointment was administered at the end of the surgical procedure. All patients were kept in a prone position for 1 to 2 weeks after surgery, at least until less than 50% gas fill.

3. Results

Table 1 summarizes patients' perioperative demographic data. Thirty-two eyes underwent 25G TSV (group A) and 30 eyes with 27G TSV (group B). There were 24 men in group A, and 18 men in group B ($p = 0.32$). The mean ± SD age was 59 ± 13 years in group A and 55 ± 9 years in group B ($p = 0.15$). Their preoperative BCVA (log MAR) was 0.44 ± 0.69 units in group A and 0.38 ± 0.61 in group B ($p = 0.73$). Their postoperative BCVA at the last visit was 0.07 ± 0.25 in group A and -0.02 ± 0.17 in group B ($p = 0.16$). The final BCVA was significantly better than the preoperative BCVA in both groups ($p = 0.02$, $p = 0.002$, resp.). The initial and final anatomical success rates were 93.8% and 100% in group A and 96.7% and 100% in group B, respectively ($p = 1$ and $p = 1$, resp.). The mean ± SD number of retinal beaks was 1.6 ± 1.2 in group A and 1.9 ± 1.2 in group B ($p = 0.30$). Twenty-three eyes had original breaks at the superior quadrant, 8 eyes at the inferior quadrant, and 1 eye at both the quadrants in group A. On the contrary, nineteen eyes had original breaks at the superior quadrant, 9 eyes at the inferior quadrant, and 2 eyes at both the quadrants in group B. There were no statistical differences in the location and the number of the breaks between both groups ($p = 0.96$). Twenty-seven eyes had RRD involving one or two quadrants, and five eyes had more extensive RRD involving three or

Table 1: Perioperative demographic data of the patients.

Characteristics	25 gauge	27 gauge	p value
Number of eyes	32	30	—
Sex, male/female	24/8	18/12	0.32
Age (years), mean ± SD	59 ± 13	55 ± 9	0.15
Preoperative visual acuity (logMAR), mean ± SD	0.44 ± 0.69	0.38 ± 0.61	0.73
Visual acuity at the last visit (logMAR), mean ± SD	0.07 ± 0.25	−0.02 ± 0.17	0.16
Preoperative intraocular pressure (mmHg), mean ± SD	13.0 ± 3.5	14.3 ± 2.8	0.11
Initial anatomical success	30 (93.8%)	29 (96.7%)	1
Final anatomical success	32 (100%)	30 (100%)	1
Number of breaks, mean ± SD	1.6 ± 1.2	1.9 ± 1.2	0.30
Location of breaks, superior/inferior/both/undetectable	23/8/1/0	19/9/2/0	0.96
Quadrant of retinal detachment, 1/2/3/4	10/17/4/1	10/17/3/0	0.99
Macular detachment, macular on/macular off	23/9	15/15	0.13
The number of sclerotomies that required sutures	9	4	0.30
Operative time (min), mean ± SD	103.3 ± 39.9	98.4 ± 28.3	0.77
Lens status, phakic/pseudophakic/aphakic	24/7/1	27/3/0	0.61

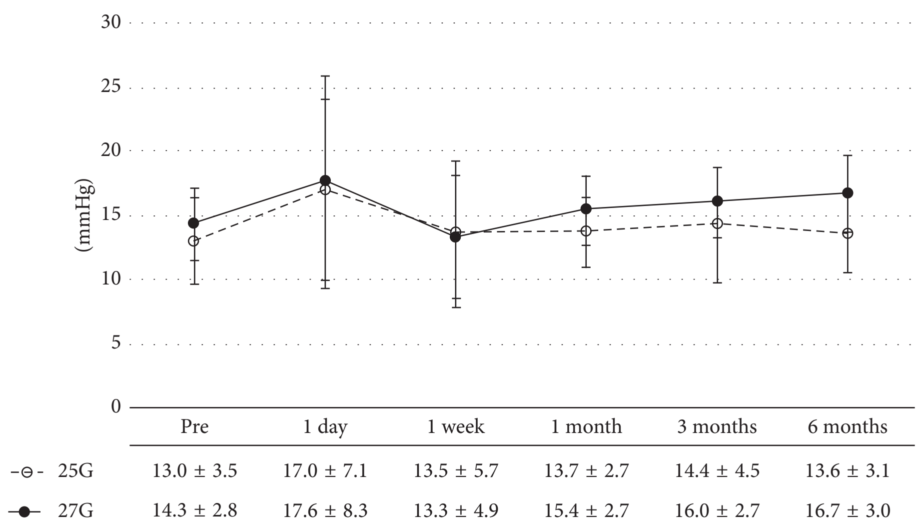

Figure 1: Time course changes in intraocular pressure (IOP). The mean IOP at baseline was 13.0 ± 3.5 mmHg in group A and 14.3 ± 2.8 mmHg in group B. At 1 day, 1 week, 1 month, 3 months, and 6 months postoperatively, the IOP was 17.0 ± 7.1, 13.5 ± 5.7, 13.7 ± 2.7, 14.4 ± 4.5, and 13.6 ± 3.1 mmHg, respectively, in group A, and 17.6 ± 8.3, 13.3 ± 4.9, 15.4 ± 2.7, 16.0 ± 2.7, and 16.7 ± 3.0 mmHg, respectively, in group B. IOP did not statistically significantly change in both groups during the follow-up period ($p = 0.63$ and $p = 0.21$, resp.).

four quadrants in group A. Twenty-seven eyes had RRD involving one or two quadrants, and three eyes had more extensive RRD involving three or four quadrants in group B. There was no statistical difference in the location and extent of RRD between both groups ($p = 0.99$). The macula was attached preoperatively in 23 (71.9%) eyes in group A and 15 (50%) in group B ($p = 0.13$). The number of wounds that required sutures was 9/96 in group A and 4/90 in group B ($p = 0.30$). The operative time (minutes) was 103.3 ± 39.9 in group A and 98.4 ± 28.3 in group B ($p = 0.77$).

We evaluated time course changes in IOP during the follow-up period. Preoperative IOP (mmHg) was 13.0 ± 3.5 in group A and 14.3 ± 2.8 in group B ($p = 0.11$). IOP did not statistically significantly change in both groups during the follow-up period ($p = 0.63$ and $p = 0.21$, resp.) (Figure 1). No eye developed postoperative hypotony in both groups.

We experienced retinal redetachment in both groups (Table 2). The rate of these complications was similar between the two groups. We performed additional 27G TSV with 20% sulfur hexafluoride gas tamponade for the treatment of retinal redetachment by experienced doctors, and all eyes obtained the final retinal attachment.

As a result of univariate analysis, the following variables were selected to perform backward logistic multiple regression analysis: age, number of quadrants involved, and lens status. The logistic multiple regression analysis revealed that all variables were not associated with the primary anatomic success (Table 3).

Table 2: Details of patients with postoperative complications.

Complication	25 gauge	27 gauge	Second treatment
Retinal redetachment	2	1	27GPPV + SF6 tamponade

27GPPV = 27-gauge pars plana vitrectomy; SF6 = sulfur hexafluoride.

Table 3: Analysis for the establishment of the relationships between explanatory variables and the primary anatomic success.

Explanatory variables	Univariate analysis	Logistic regression analysis	
	p value	p value	OR (95% CI)
Sex	0.26	NE	
Age	0.04	0.054	0.88 (0.78–1.00)
Preoperative visual acuity	0.31	NE	
Visual acuity at the last visit	0.42	NE	
Primary surgeon	0.24	NE	
Number of breaks	0.91	NE	
Location of breaks	0.44	NE	
Quadrant of retinal detachment	0.19	Not included in the model	
Macular detachment	0.28	NE	
Operative time	0.54	NE	
Lens status	0.08	Not included in the model	
Gauge of vitreous cutter	1	NE	

OR = odds ratio; CI = confidence interval; NE = not entered into multiple regression analysis.

4. Discussion

As previously reported [9, 15], in 27G TSV, the vitreous cutter used is short in length and low in stiffness, which bears clinicians, especially for surgically inexperienced doctors, concern regarding the possibility of compromised safety and operability in applying the 27G TSV system on the peripheral vitreoretinal diseases compared with the established larger-gauge TSV systems. In this study, we reported that the 27G TSV system provided anatomical results comparable to those obtained in 25G TSV. This result is compatible with the previous reports [13, 14]. In addition, the result of logistic regression analysis did not indicate any association between the primary anatomic success rate and explanatory variables, including the primary surgeon and gauge of vitreous cutter. These results indicate that 27G TSV have a potential for the practical use in the treatment of RRD for all surgeons, including inexperienced doctors.

Other concerns related to 27G TSV has been the low aspiration efficiency [15], which may extend the operation time. Mitsui et al. reported that, in 27G TSV, the operation time was significantly longer than that in 25G TSV for the epiretinal membrane [12]. On the contrary, previous reports suggested that the duration of vitreous removal is not different between 25G and 27G TSV for RRD [13, 14]. Our results also did not show a significant difference in operation time between 25G and 27G TSV for RRD. In terms of the core vitreoctomy process, the surgeon indeed felt that the aspiration efficiency of 27G TSV was obviously inferior to that of 25G TSV, as theoretically anticipated [15]. However, during the vitreous gel shaving in the vicinity of a detached retina, the critical procedure of the peripheral vitrectomy for RRD, 27G TSV was rather safe because of less frequent flapping of the retina due to lower aspiration efficiency compared with the 25G TSV. As a result, the total operation time did not differ between the two systems. Moreover, in the epiretinal membrane surgery reported by Mitsui et al. [12], peripheral vitrectomy was not as strenuous as that in RRD surgery. This difference in the required procedures could also account for the discrepant results obtained between the studies. Collectively, we believe that our results indicate the equivalency between 25G and 27G TSV for the RRD treatment. Accumulating cases are needed to confirm our preliminary observations.

Generally, 27G TSV requires a smaller incision, which suggests the possibility of excellent self-closing of the wound, compared to other vitrectomies with larger gauges [9, 15]. We monitored IOP for 6 months after surgery and found no significant difference during the follow-up period. We also found no significant difference in the number of wounds that required sutures between the two systems. In the 27G TSV performed by Mitsui et al. [12], as the stiffness of the cutter was low, the cutter had to be manipulated more dynamically; thus, wound closing might not have been as good as expected. For RRD, the cutter had to be manipulated more dynamically for the peripheral vitrectomy. This may be the reason why no difference was found between the two gauges with regard to the number of wounds that required sutures. In addition, as this research focused on the RRD, the surgery was completed by filling the vitreous cavity with SF6 gas in all the cases. Previous reports have indicated that when a gas tamponade was performed, the postoperative IOP was more stable than when it was not used [9, 16]. Therefore, the use of a gas tamponade may be a reason why the two gauges did not differ in IOP.

This study has potential limitations. First, it is a retrospective study, and there may have been a bias of patient selection. Another problem is that the sample size was relatively small. The results of large-scale, prospective research studies in the future are needed.

In conclusions, we performed a comparative study of outcomes between 25G and 27G TSV for RRD. The surgical results of the two gauges were equivalent with the similar effectiveness. We believe that 27G TSV is as useful as 25G for RRD, which is a disease of the peripheral retina.

Data Availability

The data used to support the findings of this study are restricted by the institutional review board in Kobe University School of Medicine and Kobe Kaisei Hospital in order to protect patient privacy. Data are available from Hisanori Imai, who is the corresponding author of this manuscript, for researchers who meet the criteria for access to confidential data.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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