



Vitreotomy for Complicated Retinal Detachment Without the Use of Perfluorocarbon Liquid: A Real-World Data and Retrospective Study

Ye Bai · Qi Song · Jing Liu · Qin-Xing Wu · Xue-Jiao Qin

Received: December 30, 2021 / Accepted: February 3, 2022 / Published online: February 23, 2022
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ABSTRACT

Introduction: This study aimed to evaluate the effectiveness of vitrectomy without using perfluorocarbon liquid (PFCL) for the treatment of complicated retinal detachment (RD).

Ye Bai and Qi Song have contributed equally to this paper.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s40123-022-00479-x>.

Y. Bai · X.-J. Qin (✉)
Eye Centre of Shandong University, The Second Hospital of Shandong University, No. 247 Beiyuan Street, Jinan 250012, Shandong, People's Republic of China
e-mail: qinxuejiao@hotmail.com

Y. Bai
Department of Ophthalmology, Xi'an People's Hospital, Xi'an, People's Republic of China

Q. Song
Department of Operating Theatre, Qilu Hospital of Shandong University, Jinan, People's Republic of China

J. Liu
Department of Biostatistics, School of Public Health, Cheeloo College of Medicine, Shandong University, Jinan, People's Republic of China

Q.-X. Wu
Department of Ophthalmology, The Second Affiliated Hospital of Shandong First Medical University, Taian, People's Republic of China

Methods: The utilisation of PFCL was calculated in four hospitals in 2020 and in one hospital every year from 2012 to 2020. A case series of 320 RD eyes treated with vitrectomy without the use of perfluorocarbon liquid (VWTPL) was followed up for 1–26 months. The rate of retinal reattachment (RR) and postoperative visual acuity (VA, LogMAR) was evaluated. Furthermore, factors influencing RR and VA were analysed.

Results: The overall utilisation of PFCL was 43.87% (42.74%, 45.83%, 62.39% and 4.5%). The annual utilisation was 46.94%, 20.43%, 46.73%, 47.41%, 20%, 17.24%, 7.60%, 10.67% and 4.49% from 2012 to 2020. The VA of 320 eyes improved from 1.96 ± 1.07 preoperatively to 1.43 ± 0.92 (LogMAR, $p < 0.001$) 1 week post-operation. In the follow-up of 1–26 months (median: 9 months), the primary and final RR was 87.37% and 95.56%, respectively. Age, uveitis, recurrent RD, the number of detached retinal quadrants, aPVR and preoperative VA were considered as the factors influencing postoperative VA. Moreover, preoperative VA and preoperative intraocular pressure were the factors influencing RR.

Conclusion: The utilisation of PFCL varies amongst hospitals with a highest percentage of 62.39%. VWTPL is safe and effective, thereby saving costs and preventing complications related to PFCL.

Trial Registration: ChiCTR-ORC-17014225.

Keywords: Complicated Retinal Detachment; Non-Application; Perfluorocarbon Liquids; Real-World Data; Vitrectomy

Key Summary Points

Why carry out this study?

Since its introduction in the 1980s, perfluorocarbon liquid has been widely used in vitrectomy surgery, particularly for complicated retinal detachment. This could be illustrated by the real-world data in our study. Although perfluorocarbon liquid is a useful ‘liquid tool’, it causes some troublesome complications as well as economic costs

With the development of delicate surgical instruments, it is possible to replace intraoperative perfluorocarbon liquid by surgical technique, such as air-fluid exchange, to flatten the detached retina

What was learned from the study?

The utilisation of perfluorocarbon liquid varies from 4.5 to 62.39% amongst hospitals. The primary and final retinal reattachment rate in those treated by vitrectomy without the use of perfluorocarbon liquid is not lower than those previously reported

Vitrectomy for complex retinal detachment can be performed without perfluorocarbon liquid

INTRODUCTION

Pars plana vitrectomy (PPV) is an effective surgical procedure for complicated retinal detachment (CRD). CRD refers to retinal detachment (RD) accompanied with other pathological ocular conditions, including high myopia, ocular trauma, choroid diseases, giant retinal tear, macular hole, history of cataract surgery, history of vitrectomy, severe proliferative vitreoretinopathy (PVR), intraocular inflammation, systemic immune diseases and systemic or ocular tumours. CRDs are difficult to manage, and most cases are treated by PPV or the combination of scleral buckling (SB) and PPV [1–4].

Given its high specific gravity, moderate surface tension, low viscosity and optical transparency, perfluorocarbon liquid (PFCL) was introduced in PPV in the 1980s [5], and it was primarily used to smooth out and fix the retina in CRDs [6]. PFCLs are especially helpful for the treatment of macular-involved disorders [7]. Although PFCL is an important ‘liquid tool’, it causes some complications such as retention, inflammation [8], retinal shift [9], immigration to the subretinal area [10], anterior chamber or subarachnoid space [11, 12], damage to retinal cells [13] and blindness [14]. To date, there is no evidence about the feasibility of avoiding the use of PFCLs in the treatment of CRDs.

The development of delicate surgical instruments increases the safety and efficiency of vitrectomy, allowing smaller cuts, faster cutting and more stable intraocular pressure (IOP). Thus, replacing intraoperative PFCL by air-fluid exchange to flatten the detached retina is possible, given that the vitreous traction and epiretinal membrane are removed completely. This technique is called micro-vitrectomy without the aid of PFCL (VWTPL). VWTPL can prevent PFCL-related complications, shorten operation time and decrease medical expenses. In this study, we obtained real-world data of PFCL utilisation, evaluated the performance of VWTPL in the treatment of CRD and confirmed its applicability because of its successful postoperative retinal reattachment (RR) and improved visual acuity (VA). Factors influencing postoperative VA and RR were also analysed.

DIGITAL FEATURES

This article is published with digital features, including videos, to facilitate understanding of the article. To view digital features for this article, go to <https://doi.org/10.6084/m9.figshare.19115708>.

METHODS

The study was approved by the Independent Ethics Committee on Scientific Research of Shandong University, Qilu Hospital (KLYY-2017-247), and conducted in accordance with the Declaration of Helsinki. Signed informed consent was obtained from all participants and the parent or guardian for participants < 16 years old.

Case Selection

Two kinds of cases were presented. The first case was selected to study the real-world utilisation of PFCL. Data were collected from four hospitals in 2020. Patients with RDs, who were treated by vitrectomy, were reviewed, and the use of PFCL was recorded. The same data were collected from 2012 to 2020 in one of the hospitals to explore the utilisation of PFCL every year. The four hospitals included one tertiary general hospital, one hospital focused on ophthalmology and two were local general hospitals. The proportion of PFCL applications was analysed.

The other case was collected to study the effectiveness of VWTPL. A case series of patients with CRD was collected from January 2017 to December 2020 at Qilu Hospital, Shandong University. The inclusion criterion is treatment by VWTPL (that is, without the intraoperative use of PFCL) operated on by one surgeon. Data were analysed to study the effectiveness and prognostic factors of this procedure. A total of 320 eyes from 320 patients were included. Of the 320 cases, 27 were lost to follow-up. Post-operative VA and primary and final RR rates were evaluated. Primary RR referred to the rate of retinal reattachment after the original surgery. Final RR referred to the rate of retinal reattachment at the end of follow-ups. For our patients, 1-week post-operation was a relatively fixed follow-up time point; in the following period, they might not visit the surgeon regularly, especially when the disease becomes stable or improves, so the data were most complete at 1-week post-operation.

Surgical Procedure of VWTPL

The common VWTPL procedure was conducted in the following sequence: PPV, complete removal of proliferative membrane and posterior vitreous membrane (with the aid of triamcinolone acetonide), air-fluid exchange, in situ photocoagulation and silicone oil tamponade (when necessary). The detached retina was smoothed out by simultaneous air-fluid exchange and subretinal fluid drainage from the hole (see video 1 in the online/HTML version of the manuscript). Triamcinolone acetonide was used in all cases to facilitate the dissection of the posterior vitreous adhesion or epiretinal membrane. In addition, 194 (60.63%), 23 (7.19%) and 39 (12.19%) eyes were subjected to internal limiting membrane peeling, retinotomy and cataract phacoemulsification, respectively. If the retina failed to flatten intraoperatively by air-fluid exchange even after retinotomy, usually in cases with narrow funnel-shaped RD or continuous sub-retinal hemorrhage, then PFCL would be used, and this case would not be included in this study. After the surgery, 309, 3, 5 and 3 eyes had silicone oil, C3F8, sterile air and retained perfusion fluid without air-fluid exchange, respectively.

Statistical Analyses

All data were tested for normal distribution using the Kolmogorov-Smirnov test before analyses. Statistics were performed by IBM.SPSS.20 statistics.

Percentage of PFCL utilisation was tested by descriptive statistics and chi-square test. Pre- and postoperative VA (LogMAR) changes were tested using a paired *t*-test. All VAs referred to the best corrected VA.

The factors influencing the changes in VA were tested by chi-square test, ANOVA and Kruskal-Wallis test accordingly. The positive results were subjected to ordinal logistic regression to identify the factors predictive of postoperative VA.

In addition, the factors influencing RR were tested by chi-square test, Kruskal-Wallis test, *t*-test and Mann-Whitney *U* test accordingly. The

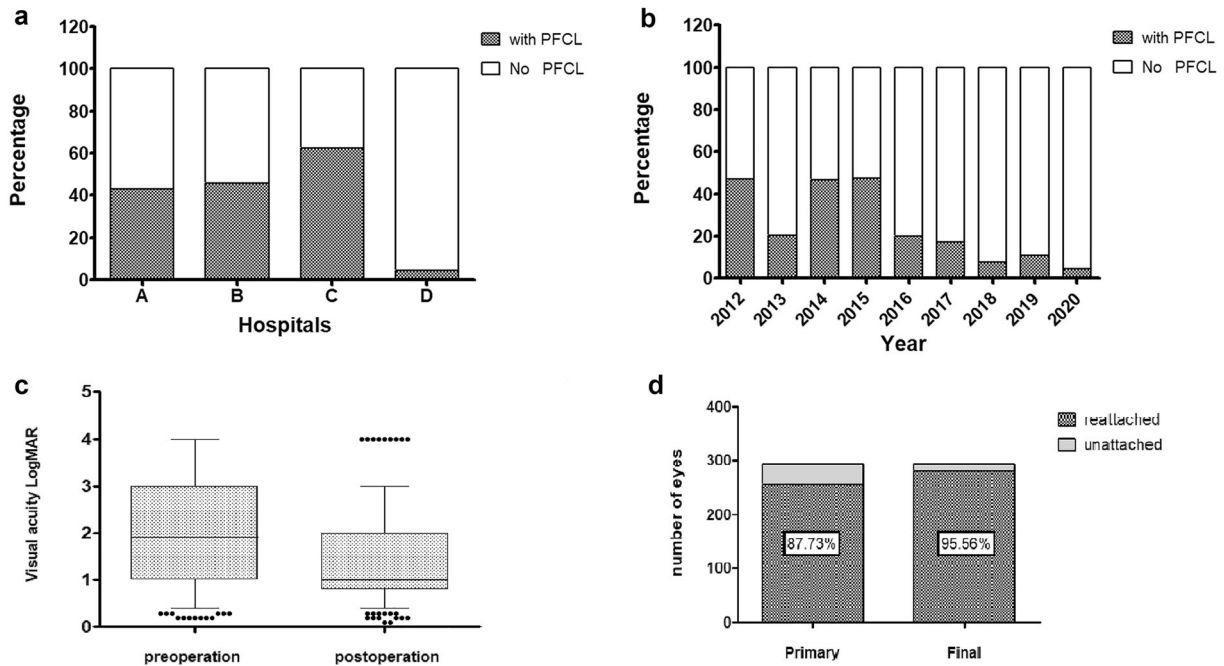


Fig. 1 Utilisation of PFCL in the real world and outcomes of VWTPL. **a** The proportion of PFCL utilisation varied amongst the four hospitals in 2020. **b** The annual proportion of PFCL utilisation in one hospital varied from 2012 to 2020. **c** For the 320 eyes subjected to VWTPL, postoperative VA was better than

preoperative VA (1.96 ± 1.07 vs. 1.43 ± 0.92 , Log MAR, $p < 0.001$, *abnormal values). **d** For the 293 followed-up eyes, the primary and final retinal reattachment rates were 87.37% and 95.56%, respectively (PFCL perfluorocarbon liquid, VWTPL vitrectomy without the aid of perfluorocarbon liquid)

positive results were subjected to binary logistic regression analysis to identify the factors predictive of RR.

The surgical results of procedures with or without PFCL were not compared because the baseline states were not equal.

RESULTS

Procedure of VWTPL

The procedure of VWTPL was presented in supplementary video 1 (see video 1 in the online/HTML version of the manuscript), and the air–fluid exchange was presented in supplementary video 2 (see video 2 in the online/HTML version of the manuscript).

Real-World Application of PFCL

The percentage of PFCL utilisation in the four hospitals was 42.74% (624/1460), 45.83% (33/72), 62.39% (287/460) and 4.5% (8/178; $p < 0.001$, chi-square test; Fig. 1a), with an overall percentage of 43.87% (952/2170). In the fourth hospital, the utilisation of PFCL per year was 46.94%, 20.43%, 46.73%, 47.41%, 20%, 17.24%, 7.60%, 10.67% and 4.49% from 2012 to 2020 ($p < 0.001$, chi-square test; Fig. 1b).

Ocular Conditions of 320 Eyes Receiving VWTPL

The patients enrolled were 14–82 (mean: 49.82 ± 14.31) years old and Chinese, including 152 (47.50%) females and 168 (52.50%) males. A total of 320 eyes suffered from CRD, including 103 with high myopia, 12 with choroid detachment, 20 with giant tear, 26 with

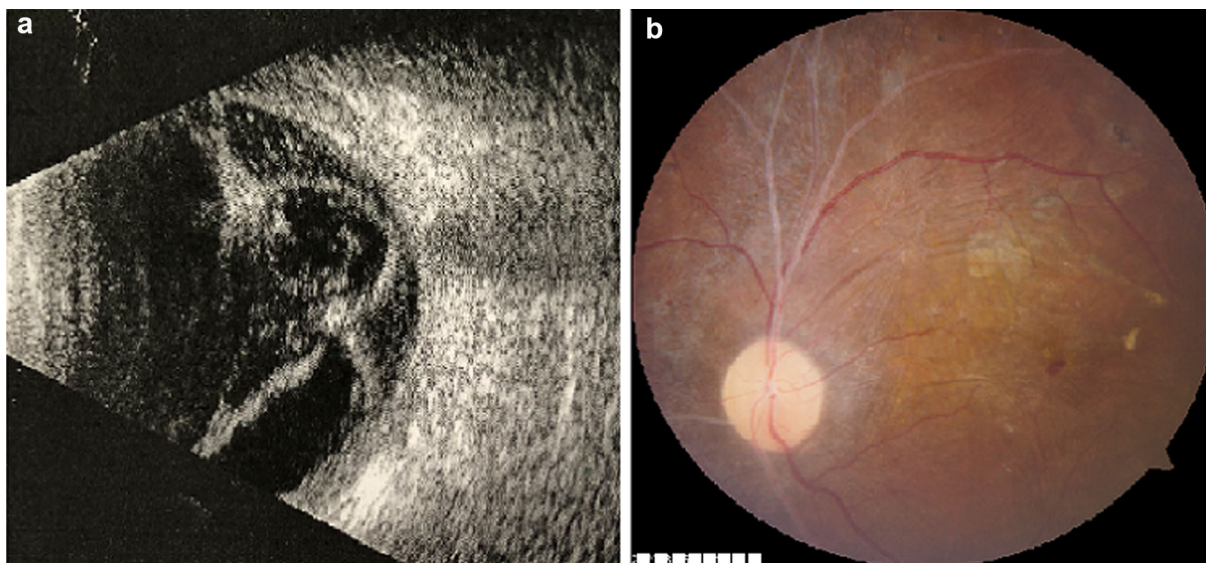


Fig. 2 Ocular examinations of a CRD patient treated by VWTPL. **a** Preoperative B ultra-scanning of the left eye showed fixed funnel-shaped RD. VA was based on hand movement (Log MAR > 2). The fundus photography was unobtainable because of complicated cataract. The patient

received VWTPL together with phacoemulsification and silicone oil tamponade. **b** The fundus photography showed retinal reattachment of the eye 3 months after silicone oil removal and intraocular lens implantation. The BCVA (Log MAR) was 0.8

macular hole, 285 with PVR CP a-c, 145 with PVR CA a-b, 35 with PDR, 80 with ocular surgery history (24 underwent vitrectomy + cataract extraction, three underwent vitrectomy + scleral buckling and others underwent only vitrectomy, cataract extraction or SB), 44 with ocular traumatic history, 29 with uveitis and 17 with recurrent RD. The macular area was detached in all eyes. In addition, one patient underwent chemotherapy for malignant tumour, and two eyes showed congenital choroid defect. Ocular conditions of a CRD patient are illustrated in Fig. 2.

Vision Recovery and Influencing Factors

Early postoperative VA was tested 1 week after VWTPL. The 320 eyes showed better VA than those before surgery (1.96 ± 1.07 vs. 1.43 ± 0.92 , LogMAR, $p < 0.001$, Fig. 1c).

Analyses of the factors that may influence postoperative VA showed that age, uveitis, recurrent RD, the number of detached retinal quadrant, aPVR and preoperative LogMAR VA

correlated with VA 1 week after the operation (Table 1).

Ordinal logistic regression test showed that uveitis ($p = 0.005$, OR = 0.07), recurrent RD ($p = 0.06$, OR = 6.37), aPVR ($p = 0.006$, OR = 0.29) and preoperative LogMAR VA ($p = 0.001$, OR = 0.53) were independent factors predicting VA 1 week after the operation.

RR and Influencing Factors

Amongst the 320 eyes subjected to VWTPL, 305 (95.31%) had retinal reattachment immediately after the operation. The reasons for the failure of retinal reattachment included retinal contraction, hemorrhage, postoperative proliferation, etc. Patients were followed up for 1–26 months, and 27 eye cases lost contact. The remaining 293 cases had a mean age of 50.86 ± 14.08 (15–82) years, including 147 males and 146 females, and they were followed up for 1–26 (median: 9) months. During follow-ups, retinal redetachment occurred in 22 silicone-oil-filled eyes. Except for the 27 lost eye

Table 1 Factors influencing postoperative VA of the 320 eyes subjected to VWTPL

Factor	Groups	VA			Statistics	p value
		Increase	Unchanged	Decrease		
Gender	Male	87	72	9	χ^2	0.15
	Female	64	74	14		
Age (mean \pm SD, years)		50.61 \pm 12.15	47.09 \pm 16.65	59.56 \pm 4.93	ANOVA	0.00
Eye	Right	74	54	12	χ^2	0.10
	Left	77	92	11		
Ocular trauma	Yes	20	24	0	K	0.10
	No	131	122	23		
High myopia	Yes	46	53	4	χ^2	0.16
	No	105	93	19		
Uveitis	Yes	26	3	0	K	0.00
	No	125	143	23		
Ocular surgery	Yes	40	38	2	χ^2	0.17
	No	111	108	21		
Lens	Phakia	128	123	23	K	0.13
	Pseudophakia	20	20	0		
	Aphakia	3	3	0		
Choroida detachment	Yes	6	6	0	K	0.63
	No	145	140	23		
Recurrent RD	Yes	0	12	5	K	0.00
	No	151	134	18		
Detached quadrants	1	30	17	5	K	0.00
	2	62	53	15		
	3	19	23	0		
	4	40	53	3		
Macular hole	Yes	10	16	0	K	0.13
	No	141	130	23		
Giant tear	Yes	12	8	0	K	0.30
	No	139	138	23		

Table 1 continued

Factor	Groups	VA			Statistics	<i>p</i> value
		Increase	Unchanged	Decrease		
No. of quadrants with hole	0	58	65	10	K	0.49
	1	70	63	11		
	2	18	11	2		
	3	0	5	0		
	4	5	2	0		
Posterior PVR (CP a-c)	Yes	135	131	19	K	0.59
	No	16	15	4		
Anterior PVR (CA a-b)	Yes	20	47	7	χ^2	0.00
	No	131	99	16		
PDR	Yes	21	12	2	K	0.28
	No	130	134	21		
Course of RD, (days)	Median/mean rank	12/139.41	23/175.20	60/205.67	K	0.00
Preoperative VA, (LogMAR)	Median/mean rank	2/175.57	1.75/147.50	1.7/144.09	K	0.02
Preoperative IOP, (mmHg)	Median/mean rank	10.5/156.11	10.7/159.05	13/198.05	K	0.12

χ^2 chi-square test, *K* Kruskal-Wallis test, *ANOVA* analyses of variance
P < 0.05 was considered statistically significant

cases, the primary RR rate was 87.37% (256/293, Fig. 1d).

Amongst the 15 eyes whose retina was not restored immediately after VWTPL, five received a second VWTPL, which restored the retina, whereas the other ten eye cases refused a second VWTPL and remained unchanged until the last follow-up. All 22 eyes with retinal redetachment underwent second VWTPL, which restored the retina in 19 eyes, whereas 3 eyes were detached in situ. A total of 13 eyes had failed retinal restoration. Except for the 27 lost eye cases, the final RR rate was 95.56% (280/293, Fig. 1d).

Analyses of the factors that may influence RR showed that preoperative LogMAR VA and preoperative IOP influenced the primary RR. Low VA (high LogMAR) and low IOP may impede retinal restoration (Table 2).

DISCUSSION

CRD is difficult to handle because of the accompanying pathological conditions. PPV is better than SB with improved postoperative VA in the treatment of pseudophakic/aphakic RDs [15, 16], although the primary and final RR rates could hardly achieve 100%.

PFCLs are commonly used during PPV. According to this study, PFCL utilisation varied from 4.5 to 62.39%. In our hospital, where PFCL was used the least in 2020, PFCL utilisation has tended to decrease over the past 9 years. Thus, we utilised micro-incision PPV to avoid the above-mentioned PFCL-related complications. This procedure can achieve high-speed cutting and maintain a stable IOP, thereby smoothening out the retina by the surface tension of the gas with gas-fluid exchange without the use of PFCL [17]. This procedure is called VWTPL. All tractions and proliferations should be relieved

Table 2 Factors influencing the primary retinal reattachment of 293 eyes subjected to VWTPL

Factor	Groups	Reattached eyes	Unattached eyes	Statistics	<i>p</i>
	Total	256 (87.37%)	37 (12.63%)		
Gender	Male	124	23	χ^2	0.16
	Female	132	14		
Age (mean \pm SD, years)		51.05 \pm 13.96	49.14 \pm 16.23	<i>t</i>	0.35
Eyes	Right	106	21	χ^2	0.08
	Left	150	16		
Ocular trauma	Yes	29	8	χ^2	0.11
	No	227	29		
High myopia	Yes	83	12	χ^2	0.99
	No	173	25		
Uveitis	Yes	24	2	χ^2	0.55
	No	232	35		
Ocular surgery	Yes	64	10	χ^2	0.79
	No	192	27		
Len	Phakia	217	32	K	0.75
	Pseudophakia	33	5		
	Aphakia	6	0		
Choroidal detachment	Yes	9	1	χ^2	1.00
	No	247	36		
Recurrent RD	Yes	13	2	χ^2	1.00
	No	243	35		
Detached area (quadrants)	1	47	3	K	0.09
	2	104	15		
	3	32	4		
	4	73	15		
Macular hole	Yes	21	4	χ^2	0.54
	No	235	33		
Giant tear	Yes	17	2	χ^2	1.00
	No	239	35		

Table 2 continued

Factor	Groups	Reattached eyes	Unattached eyes	Statistics	<i>p</i>
Quadrants with holes	0	110	11	K	0.07
	1	116	18		
	2	21	7		
	3	4	0		
	4	5	1		
Posterior PVR (CP a-c)	Yes	227	32	χ^2	0.78
	No	29	5		
Anterior PVR (CA a-b)	Yes	54	11	χ^2	0.24
	No	202	26		
PDR	Yes	28	1	χ^2	0.15
	No	228	36		
Course of disease, days (median/mean rank)		20.5/149.86	14/127.19	U	0.13
Preoperative VA, LogMAR (median/mean rank)		1.8/143.03	3.0/174.47	U	0.03
Preoperative IOP (median/mean rank)		11.20/154.84	8.7/92.78	U	0.00

χ^2 chi-square test, *t* *t*-test, *K* Kruskal-Wallis test, *U* Mann-Whitney *U* test; *p* value *P* < 0.05 was considered statistically significant

Table 3 Summary of surgical outcomes for RD

Author	Cases	PPV	PL	PRR %	FRR %	Preoperative VA LogMAR	Postoperative VA LogMAR	<i>p</i> value	Reference
Chiharu	27	25G	No	77.80	92.60	1.36 ± 0.81	0.75 ± 0.78	< 0.001	[18]
Paraschos	51	20/23G	No	80.00	84.00	2.45 ± 0.66	1.37 ± 0.75	0.001	[19]
Liu	21	–	Some	–	90.50	1.93 ± 0.48	1.52 ± 0.45	0.001	[20]
Mohammad	370	P/20/23G	All	84.50	92.97	2.33 ± 0.83	1.48 ± 0.92	< 0.001	[21]
Our study	128	23G	No	86.44	95.76	1.97 ± 1.06	1.43 ± 0.92	< 0.001	

– unknown, *PRR* primary reattachment rate, *FRR* final reattachment rate

before gas-fluid exchange. In our study, comparative analysis was not applied because the number of cases with PFCL was fewer than those without PFCL. The evaluation of

postoperative VA and RR rates showed similar or better results than previously reported [18–21] (Table 3), though the study group was not equivalent to those studies; these results

suggested that VMTPL is a sound stratagem. A comparative study comparing the use of PFCL and subretinal fluid drainage reported a 90.7% PRR and 100% FRR for both groups [22].

In our study, retina was unattached in 13 eyes, 10 of which occurred in the inferior peripheral area. This result may be due to the proliferative stiffening and horizontal traction of the local retina. A combination of SB [23], heavy silicone oil tamponade [24] or retinotomy [25] may be used.

Factors associated with RR failure include choroid detachment, considerable hypotony, PVR, total RD, large retinal breaks [26] and extent of retinectomy [27]. The presence of preoperative PVR and the development of postoperative PVR primarily contributed to the failure of RR [28, 29]. In our study, low preoperative VA and decreased preoperative IOP were considered as factors unfavourable to RR in VWTPL treatment. Low IOP and a large detachment area may hamper the ‘pump function’ of retinal pigment epithelium and decrease the adhesion of the interphotoreceptor matrix [30, 31], making retinal replacement difficult. Though not demonstrated in our study, the factor ‘young age’ may be an unfavourable factor for RR because young people have a high risk of developing PVR because the younger the patient is, the higher the ability of self-repair of retinal tissues [32]. Although not evaluated in our study, ‘surgical experience’ is also a substantial factor indicating the success rate [27].

The factors that are favourable to postoperative VA include reattached retina (particularly macula), slight P(D)VR, good preoperative VA, postoperative shape of the macular fovea and regular distribution of laser spots [27]. Intraoperative photocoagulation may decrease the possibility for retinal redetachment and aid the recovery of VA [4]. By contrast, the factors that are unfavourable to postoperative VA include rhegmatogenous RD, transverse trauma, inflammation (endophthalmitis, uveitis, retinitis, etc.) and preoperative PVR, particularly its grading. Our study on VWTPL surgery showed similar results. For example, recurrent RD, anterior PVR and worse preoperative VA are factors unfavourable to postoperative VA of

patients with RD treated with VWTPL. Furthermore, although uveitis is unfavourable to RR, it was related to a good prognosis of postoperative VA.

The limitation of this study is that no randomised comparative design was applied because of the imbalance between sample sizes. There are relevant biases related to the retrospective study and a long-term VA results need to be analysed. Also, the study population is somewhat heterogeneous due to the simplex selection criteria.

CONCLUSIONS

In this study, the utilisation of PFCL varies amongst hospitals, and it can be spared in most cases. VWTPL is an effective and efficient surgical treatment for CRD, thereby saving the use of PL and avoiding related complications.

ACKNOWLEDGEMENTS

Funding. Sponsorship for this study, and the journal’s Rapid Service Fee, were funded by the Technical Innovation Foundation for Clinical Medicine by Jinan Science and Technology Bureau (grant no. 201704122), the Department of Science and Technology of Shandong Province (grant no. ZR201702190277) and the Research Start-up Funds for Introduced Talents by the Second Hospital of Shandong University (YY-2021-001). The funders had no role in the study design, data collection and analysis, decision to publish or preparation of the manuscript.

Authorship. All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

Author Contributions. Xue-Jiao Qin and Qi Song designed the study. Xue-Jiao Qin, HMC and Ye Bai were the major contributors to the

writing of the manuscript. Ye Bai, Qin-Xing Wu and Xue-Jiao Qin carried out the operations. Ye Bai, Qi Song and Qin-Xing Wu enrolled and managed the patients. Ye Bai and Jing Liu analysed and interpreted the data. All authors read and approved the final manuscript.

Disclosures. Ye Bai, Qi Song, Jing Liu, Qin-Xing Wu and Xue-Jiao Qin declare that they have no conflict of interest.

Compliance with Ethics Guidelines. The study complies with the protocols reviewed and approved by the Independent Ethics Committee on Scientific Research of Shandong University, Qilu Hospital and the tenets of the Helsinki Declaration of 1964 (and its later amendments). The clinical trial registration number of this study is ChiCTR-ORC-17014225. Signed informed consent was obtained from all participants and the parent or guardian for participants under 16 years old.

Data Availability. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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