

Outcomes of transconjunctival sutureless 27-gauge vitrectomy with silicone oil infusion

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Abstract

Purpose To demonstrate the safety and efficacy of 27-gauge pars plana vitrectomy (PPV) in selected patients with vitreoretinal diseases requiring silicone oil (SO) tamponade.

Methods Retrospective review of a consecutive interventional case series at a single center.

Results Twenty-one eyes of 19 patients were included in the study. The indications for PPV and SO tamponade were as follows: fibrovascular tractional retinal detachment (12 eyes), rhegmatogenous retinal detachment with proliferative vitreoretinopathy (three eyes), primary rhegmatogenous retinal detachment (two eyes), macular hole (two eyes), vitreous hemorrhage (one eye), and endophthalmitis (one eye). All eyes underwent transconjunctival sutureless 27-gauge PPV with either 1000-cS (16 eyes) or 5000-cS (five eyes) SO tamponade. No intraoperative complications occurred. Mean preoperative best-corrected visual acuity (BCVA) was 20/300 (range, light perception to 20/40; median, counting fingers). Mean postoperative BCVA was 20/160 (range, no light perception to 20/25; median 20/300; $p=0.022$). Follow-up was 6.4 ± 8.8 months (range, 1–38 months; median, 4 months). No complications relating to 27-gauge placement of SO were observed.

Conclusions Results show that 27-gauge PPV with SO injection appears safe, is efficient, and may be considered for the surgical management of vitreoretinal diseases requiring SO tamponade.

Keywords 27-gauge · Silicone oil · Vitrectomy · Vitreoretinal diseases

Introduction

The advent and subsequent refinement of microincisional vitrectomy surgery (MIVS) techniques represent some of the most transformative changes in vitreoretinal surgery over the past 15 years. Improved surgical precision and less collateral surgical trauma have benefitted patients and vitreoretinal surgeons alike [1–4].

The use of 23- and 25-gauge instrumentation offers numerous potential advantages over traditional 20-gauge surgery, and has been widely adopted in the management of a broad array of vitreoretinal diseases, including those requiring the infusion of silicone oil (SO) [5–13]. Since the introduction of transconjunctival sutureless 27-gauge vitrectomy by Oshima in 2010 [14], several different 27-gauge pars plana vitrectomy (PPV) platforms have been developed and brought to market [15–18]. As was the case with the introduction of 25-gauge PPV over a decade ago, the advantages, disadvantages, indications, and contraindications of this new modality are being elucidated.

The National Eye Institute Silicone Study demonstrated the effectiveness of SO tamponade in cases of complex retinal detachment (RD) associated with advanced proliferative vitreoretinopathy (PVR), diabetic tractional retinal detachment (TRD), giant retinal tears, primary RD, and macular hole surgery [19–21].

This study was performed at the Cincinnati Eye Institute and University of Cincinnati, Department of Ophthalmology

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When 25-gauge PPV was first introduced, initial reports of successful surgery were limited to simple uncomplicated pathologies [2, 3, 22]. At that time, 25-gauge SO infusion was not considered feasible due to gauge-related fluidic concerns as well as concerns relating to the difficulties in managing the more complex pathologies for which SO is often indicated with the more fragile 25-gauge instrumentation. Silicone oil placement without a larger oil injection wound was considered a relative contraindication to 25-gauge surgery [23]. Subsequent reports, however, demonstrated safe and efficient utilization of SO in the setting of 25-gauge surgery [10–12]. As with 25-gauge surgery, it is reasonable to assume that there may be a similar hesitancy or perceived limitations regarding SO infusion with the even smaller instrumentation of 27-gauge PPV. Although several reports of 27-gauge PPV have been published, none have reported 27-gauge SO infusion [14–18].

In this retrospective study, we report our experience with transconjunctival sutureless 27-gauge vitrectomy and SO injection in the surgical management of vitreoretinal cases. We also describe our technique for SO infusion with 27-gauge instrumentation.

Materials and methods

A retrospective chart review was performed for all patients who underwent transconjunctival sutureless 27-gauge PPV and SO tamponade for vitreoretinal diseases at the Cincinnati Eye Institute (Cincinnati, OH) from January 2012 to April 2015. All patients provided written informed consent before surgery, and all data collection was performed in accordance with the Health Insurance Portability and Accountability Act (HIPAA) and the Declaration of Helsinki. Surgeries were performed by a single surgeon (CDR).

Information abstracted from the patient record included age, sex, ophthalmic history, surgical case time, pre- and postoperative Snellen best-corrected visual acuity (BCVA), follow-up duration, anterior segment and fundus examination findings, and intraoperative and postoperative complications. All patients who underwent 27-gauge PPV with SO tamponade are reported, and no patients were excluded from the study.

Surgical technique

Local anesthesia with monitored anesthesia care was administered through retrobulbar, peribulbar, or subconjunctival routes in all patients. The periocular skin was prepared with 5 % povidone-iodine followed by a drop of povidone-iodine in the inferior fornix. The eye was prepared and draped in standard fashion, and a lid speculum was inserted. Simultaneous clear corneal cataract surgery was performed by the vitreoretinal surgeon using standard phacoemulsification techniques on all

patients in whom a visually significant cataract precluded adequate visualization for the operative procedure and postoperative care. The vitrectomy systems used in 27-gauge PPV procedures were the Constellation Vision System (Alcon, Ft. Worth, TX) in 17 eyes, the Associate system (Dutch Ophthalmic Research Center [DORC] International B.V., Zuidland, Netherlands) in three eyes, and the VersaPACK (Synergetics USA, Inc., O'Fallon, MO) running on the Accurus Surgical System (Alcon) in one eye. The surgical approach consisted in displacing the conjunctiva over the sclerotomy, which was then created with a 27-gauge trocar/cannula system. Cannulas were placed inferotemporally, superotemporally, and superonasally 3 mm posterior to the limbus in pseudophakic eyes, and 4 mm in phakic eyes. A 30° angle of entry was used for trocar placement. The infusion cannula was connected to the inferotemporal cannula. The peripheral fundus was visualized using the Merlin noncontact viewing system (Volk Optical, Inc., Mentor, Ohio) or the BIOM noncontact wide-angle viewing system (Oculus Surgical, Inc., Wetzlar, Germany). A disposable contact lens (DORC International B.V.) was used for visualization during macular dissection.

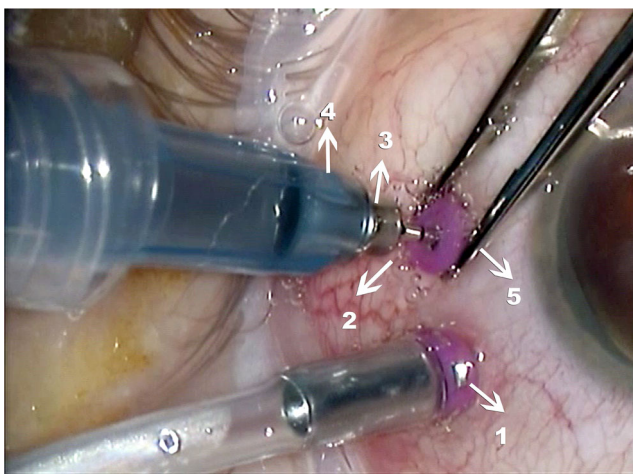
The surgical procedures varied depending upon the diagnosis and whether prior PPV had been performed. Core vitrectomy was performed in cases without prior vitrectomy, with subsequent peripheral vitreous dissection when necessary. Fibrovascular membrane peeling was performed utilizing the vitreous cutter, disposable 27-gauge end-grasping or internal limiting membrane forceps, and disposable curved 27-gauge scissors (Alcon, DORC, Synergetics). The 27-gauge vitrectomy instrument was used to dissect and/or trim fibrovascular tissue in areas of dense adhesions and, when necessary, to perform retinectomy. A chandelier light source (Alcon or Synergetics) was used when bimanual surgery was required. A directional endolaser (Alcon, DORC, Synergetics) was utilized to treat retinal breaks and ischemic retina, and/or to apply scatter photocoagulation. Transvitreal diathermy was used to mark retinal breaks and retinectomy sites and to achieve intraocular hemostasis. Perfluorocarbon liquid (PFCL; Alcon) was utilized to stabilize the retina in cases of complex RD. Indocyanine green (ICG; Akorn, Inc., Lake Forest, IL) was used for macular staining. PFCL and ICG infusion were performed using a 1.25-inch 27-gauge needle (Becton-Dickinson, Franklin Lakes, NJ), SideFlō cannula (MedOne Surgical, Inc., Sarasota, FL), or soft-tip extrusion needle (Alcon, Dutch, MedOne, Synergetics). Fluid–air exchange and subretinal fluid drainage were performed with a soft tip cannula (MedOne, Alcon, Synergetics, DORC).

Silicone oil infusion technique

Silicone oil infusion was performed in each case after a complete air–fluid exchange. This portion of the surgery was performed by a single surgeon, without a skilled surgical

assistant. A 27-gauge SO vent was placed in the superonasal vitrectomy cannula to open the valve and allow appropriate venting. The air infusion was set to 30 mmHg to maintain a formed globe throughout the SO injection. This was lowered to 10 mmHg once the SO level was nearly complete. A 25-gauge SO injection cannula (Alcon) or a 24-gauge Angiocath (Becton-Dickinson) trimmed to 2.0 mm was loaded onto the viscous fluid injection syringe and docked into the remaining superotemporal 27-gauge vitrectomy cannula. This was held in place with firm back pressure on the vitrectomy cannula from a 0.3-mm forceps. For right eyes, the SO syringe was held in the right hand and the 0.3-mm forceps in the left hand, and for left eyes, the syringe was held in the left hand and the forceps in the right hand. Silicone oil was injected at 80 psi while manually maintaining a constant but gentle force on the vitrectomy cannula/SO cannula dock throughout the injection (Fig. 1). The dock was released and the 27-gauge vitrectomy cannulas were removed after the desired SO fill was achieved. The residual sclerotomy tunnels were crushed closed with firm point pressure from the tip of a 0.12-mm forceps. All eyes were examined for evidence of SO leakage at all postoperative visits.

All data were tabulated and analyzed with Microsoft Excel (Microsoft Corp., Redmond, WA). Snellen visual acuity values were converted to a rank system for quantitative analysis and statistical purposes (Table 1) [10]. Two-tailed paired Student *t* tests and χ^2 tests were used for statistical



- 1) 27 gauge vitrectomy cannula with inserted infusion cannula inferotemporally
- 2) 27 gauge vitrectomy cannula superotemporally
- 3) 25 gauge silicone oil injection cannula "docked" into the wide extraocular part of the superotemporal 27 gauge vitrectomy cannula
- 4) Terminal end of silicone oil injection syringe
- 5) 0.3 mm forceps grasping the superotemporal vitrectomy cannula to create counterpressure for the "dock"

Fig. 1 Intraoperative photograph of silicone oil infusion at 80 psi using a 25-gauge SO injection cannula docked into the 27-gauge vitrectomy cannula, which is held in place with firm back pressure from a 0.3-mm forceps

comparisons. Data are reported as mean \pm SD unless otherwise noted. *P* values <0.05 were regarded as statistically significant.

Results

Patient data is summarized in Table 2. The 27-gauge PPV with SO tamponade was performed on 21 eyes of 19 patients. Twelve men and seven women (mean age, 57.9 ± 15.8 years; median, 58.5 years) were followed for a mean of 6.4 ± 8.8 months (range, 1–38 months; median, 4 months). Surgical indications included fibrovascular TRD (12 eyes), rhegmatogenous RD with PVR (three eyes), primary rhegmatogenous RD (two eyes), macular hole with concurrent medical disease restricting postoperative face-down positioning (two eyes), severe vitreous hemorrhage with siderosis bulbi and hypotony in a patient receiving anticoagulants (one eye), and endophthalmitis (one eye).

The mean preoperative BCVA was 20/300 (range, light perception [LP] to 20/40; median, counting fingers), and the mean postoperative BCVA was 20/160 (range, no light perception [NLP] to 20/25; median, 20/300; $P=0.022$). Postoperative BCVA improved in 12 eyes (57 %), remained unchanged in four (19 %), and declined in five (24 %) (Fig. 2). No eyes developed phthisis bulbi or pain requiring enucleation or evisceration.

Twelve of 21 eyes (57 %) had undergone prior vitrectomy. Nine eyes (43 %) were pseudophakic and 12 (57 %) were phakic at the time of 27-gauge PPV with SO. Simultaneous cataract surgery was performed on eight (67 %) of these 12 eyes. Membrane peeling was performed on 17 (81 %) eyes, and endolaser was placed in 16 (76 %). Relaxing retinectomy procedures were carried out in six eyes (29 %), and PFCL was utilized in five (24 %). Five eyes (24 %) received 5000-cS SO, and 16 eyes (76 %) received 1000-cS SO. Silicone oil injection times were not precisely measured; however, 1000-cS SO was injected in approximately 1 min, and 5000-cS SO was injected in approximately 3–4 min.

The mean surgical time was 65.6 ± 30.1 min (range, 27 to 125 min; median, 66 min). In eyes with prior vitrectomy, the mean surgical time was 51 ± 24.5 min, and in eyes without prior vitrectomy, it was 85.2 ± 26.2 min ($P<0.05$).

No intraoperative complications occurred. Minimal egress of a few SO droplets was noted in most cases immediately after removal of the vitrectomy cannulas. This was more notable with 1000-cS than 5000-cS SO, and was easily resolved by crushing the sclerotomy tunnel closed with point pressure from the closed tips of a 0.12-mm forceps. None of the eyes required sclerotomy suture placement. The posterior segment SO fill was between 95 and 100 % postoperatively, and did not change throughout the follow-up period in any eyes. No instances of subconjunctival SO migration occurred.

Table 1 Visual acuity rank conversion

Snellen VA	NLP	LP	HM	CF	20/400	20/300	20/250	20/200	20/160	20/125	20/100	20/80	20/70	20/60	20/50	20/40	20/30	20/25
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

VA visual acuity, NLP no light perception, LP light perception, HM hand motions, CF counting fingers

Postoperative complications were noted in three eyes. One eye developed recurrent RD due to severe PVR 5 months after the first surgery for diabetic TRD. The retina was successfully reattached with subsequent surgery, but visual acuity was NLP due to severe diabetic ischemia. This patient died 19 months later from systemic complications of diabetes. One phakic eye developed SO-related aqueous misdirection glaucoma as a result of zonular insufficiency from previous blunt trauma. This required reoperation with SO removal and placement of a gas bubble 8 days postoperatively. One eye that underwent surgery for recurrent RD and PVR developed recurrent severe PVR under oil 5 months after the initial surgery, requiring reoperation with PPV and gas tamponade. Three months later, the patient developed hypotony due to recurrent severe anterior loop PVR and epicyliary membrane formation, which was successfully treated with endoscopic PPV, epicyliary membrane peeling, explantation of the posterior chamber intraocular lens, and SO placement. Two additional patients had excellent anatomical results after 27-gauge PPV and SO placement but went on to NLP final visual acuity due to severe diabetic retinal ischemia.

Discussion

Repeated review of the literature identified this paper as the first report to demonstrate the feasibility of SO infusion in conjunction with 27-gauge PPV, and to suggest that the need for SO placement is not a contraindication for 27-gauge surgery. The 27-gauge PPV platform is a new surgical modality, for which advantages and disadvantages are still being elucidated. Disadvantages of 27-gauge surgery relate to the fluidic restrictions inherent in small-diameter tubing and the increased flexibility and fragility of small-gauge instrumentation. Initial experiences with first-generation 27-gauge PPV systems were with straightforward, uncomplicated vitreoretinal pathology [14–16]. However, as surgeons have become more experienced, and next-generation 27-gauge equipment has been developed, striking advantages in precision and control of the vitreous cutter on the surface of the retina are increasingly being recognized. The combination of small 27-gauge cutter port size and ultra-high cut rates with preserved duty cycle yields improved vitreous cutter efficiency, with a very limited sphere of influence. This allows for increased control at the cutter tip and may reduce distal traction [15, 24, 25]. The 27-gauge cutters may be preferable for complex pathologies,

where precise control of the cutter on the retinal surface allows it to serve as a multifunction tool for dissection and removal of membranes, reducing the need for bimanual manipulations [15, 24, 25]. The 27-gauge vitrectomy surgery technology is rapidly finding a niche in more complex surgical cases such as TRD, RRD, and PVR, in which SO infusion is often indicated. Although we acknowledge that surgical indications and contraindications continue to evolve, as they did with 25-gauge PPV, we believe that 27-gauge PPV will be a broadly capable surgical platform in the future. Further discussion of details of the surgical indications and contraindications for 27-gauge PPV is beyond the scope of this paper.

Other reported advantages of smaller PPV incisions include faster visual recovery, improved patient comfort, reduced corneal astigmatism, less inflammation, and less disruption of the conjunctiva [26–28]. While self-sealing sclerotomy reduces the need for conjunctival peritomy and suturing, improper self-sealing has been linked to postoperative complications including hypotony, choroidal detachment, retinal break formation, and endophthalmitis [29–33]. The smaller incisions with 27-gauge PPV may reduce the risk of such complications compared to 23- and 25-gauge PPV [34]. Our report indirectly supports the advantage of smaller wound size in reducing SO leakage from unsutured sclerotomy wounds. Subconjunctival SO migration is a known complication of MIVS, and some authors have suggested a low threshold for sclerotomy suture placement in MIVS with SO infusion [35, 36]. The fact that no SO migration occurred in our small case series supports this contention, and suggests a further reason to consider 27-gauge surgery when SO placement is planned.

Curved scissors were used for some diabetic membrane dissections early in the series when first-generation 27-gauge vitrectomy surgical systems were used. These had low cut rates, in the range of 1500–2500 cpm, and spring-return cutters with limited duty cycle; they were early in the learning curve of 27-gauge PPV, and even earlier in the learning curve of 27-gauge PPV with SO tamponade. As surgeon experience, cut rates, and duty cycle of the vitrectomy systems improved, we abandoned the scissors in favor of using the vitreous cutter probe on the retinal surface for all segmentation and delamination maneuvers. A cut rate of 7500 cpm with preserved duty cycle of 50 % or higher was utilized for the later cases.

In this case series, five eyes were injected with 5000-cS SO and 16 eyes with 1000-cS SO. The choice of silicone oil viscosity was based on surgeon preference and the anatomical fact pattern in the eye. The 5000-cS SO was more often placed

Table 2 Patient data

Eye	Age	Sex	Diagnosis	Prior PPV	Lens	Procedure	SO (cS)	Pre-op VA	Post-op VA	Complications	Follow-up (months)	Comments
1	86	F	Severe VH and hypotony	Yes	PCIOL	PPV	1000	LP	20/250		3	Siderosis bulbi
2	44	F	TRD	Yes	Phakic	Phaco, PPV, MP, EL	1000	HM	LP		1	PDR, lost to follow-up
3	33	M	TRD	Yes	Phakic	PPV, MP, EL	5000	CF	20/80	Misdirection glaucoma	6	PDR
4	47	F	TRD	No	Phakic	Phaco, PPV, MP, EL	5000	20/160	20/70		4	PDR
5	67	F	RRD, PVR	Yes	PCIOL	PPV, MP, retinectomy, PFCL	5000	20/125	20/125		2	PDR
6	35	F	TRD	No	Phakic	PPV, MP, retinectomy, PFCL, EL	1000	LP	NLP		6	PDR
7	83	M	TRD	Yes	PCIOL	PPV, MP, EL	1000	CF	CF		2	CRVO
8	48	M	TRD, PVR	No	Phakic	Phaco, PPV, MP, EL	1000	HM	HM		2	PDR
9	62	M	TRD	No	PCIOL	PPV, MP, EL	1000	20/50	20/40		5	PDR
10	65	M	Macular hole	Yes	PCIOL	PPV, MP	1000	20/125	20/30		5	PDR
11	54	F	RRD, PVR	Yes	Phakic	Phaco, PPV, MP, PFCL, retinectomy, EL	1000	HM	CF		3	
12	71	M	Endophthalmitis	Yes	PCIOL	PPV, MP, retinectomy, EL	1000	HM	CF		2	
13	78	F	Macular hole	Yes	PCIOL	PPV, MP	1000	CF	20/80		38	
14	59	M	RRD, PVR	Yes	Phakic	PPV, retinectomy, EL	1000	20/160	20/400	Recurrent PVR	8	
15-R ^a	40	M	TRD	No	Phakic	Phaco, PPV, MP, EL	5000	20/400	20/200		2	PDR
16-L ^a	40	M	TRD	No	Phakic	Phaco, PPV, MP, retinectomy, EL	5000	CF	NLP		2	PDR
17-R ^b	58	M	TRD	No	Phakic	Phaco, PPV, MP, EL	1000	20/400	20/40		20	PDR, patient expired
18-L ^b	58	M	TRD	No	Phakic	Phaco, PPV, MP, EL	1000	CF	NLP		18	PDR, patient expired
19	70	M	RRD	No	PCIOL	PPV, PFCL, EL	1000	CF	20/25	Recurrent TRD	1	
20	40	M	TRD	Yes	Phakic	PPV, MP, EL	1000	20/40	20/40		1	PDR
21	61	M	RRD	Yes	PCIOL	PPV, PFCL, EL	1000	20/50	20/40		1	

PPV pars plana vitrectomy, SO silicone oil, cS centistroke, VA visual acuity, VH vitreous hemorrhage, PCIOL posterior chamber intraocular lens, LP light perception, TRD tractional retinal detachment, MP membrane peeling, EL endolaser, HM hand motions, PDR proliferative diabetic retinopathy, CF counting fingers, RRD rhegmatogenous retinal detachment, PVR proliferative vitreoretinopathy, PFCL perfluorocarbon liquid, NLP no light perception, CRVO central retinal vein occlusion.

^a Eyes number 15 and 16 are the right and the left eyes of the same patient

^b Eyes number 17 and 18 are the right and the left eyes of the same patient

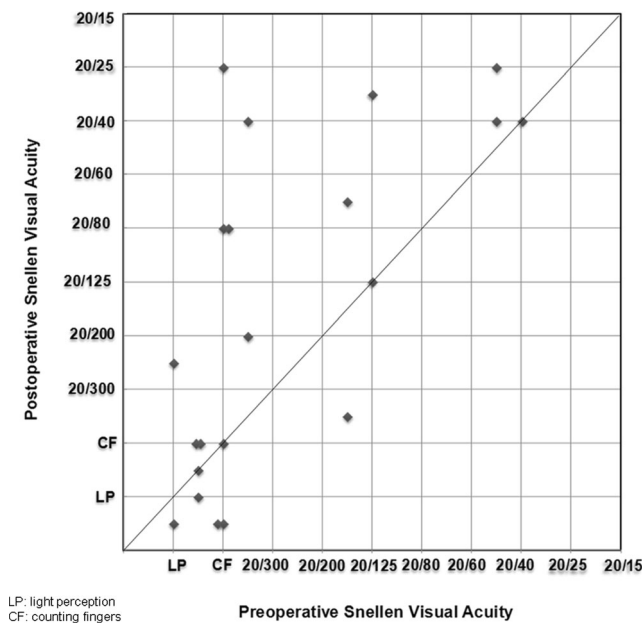


Fig. 2 Preoperative and postoperative visual acuity measurements in 21 eyes undergoing 27-gauge pars plana vitrectomy and silicone oil tamponade

into eyes with advanced PVR or PDR with TRD. Oils of both viscosities were able to be placed safely; however, the efficiency of the 1000-cS SO injection was significantly higher. Although 5000-cS SO infusion is possible with 27-gauge instrumentation, it is more challenging than 1000-cS SO due to the small lumen diameter for injecting cannulas. This technical difficulty has been alleviated by a new 27-gauge SO injection cannula (MedOne) which has been available since January 2016 (personal communication by CDR with MedOne). Silicone oil removal with 27-gauge cannulas is much more difficult. High positive pressures in excess of 4000 mmHg are available for injection of SO, but vacuum levels are limited by the laws of physics to 700 mmHg. Therefore, SO removal through 27-gauge cannulas remains problematic.

As this is the first series of 27-gauge PPV with SO placement known to us, no comparison groups exist in the literature. We chose to compare this series of 21 eyes that underwent 27-gauge PPV with SO tamponade with our previously published cohort of 35 eyes that underwent 25-gauge PPV and SO tamponade [10]. These were the first 25-gauge surgeries with SO tamponade performed at our center, and the first reported series published in the literature. We felt that for any comparison to be valid, it was important to consider the learning curves involved in the first infusions of SO with both 25- and 27-gauge surgery. All available records from the previously published series were re-reviewed. Surgical indications and mean preoperative and postoperative BCVA, follow-up, and surgical case times were very similar between the two procedures, and are detailed in Table 3. No significant intraoperative complications were experienced by either the 25-gauge or the 27-gauge PPV group.

Postoperative complications were also similar between the 27- and 25-gauge groups. Both patient cohorts had one eye each with recurrent RD due to PVR and one RD after surgery for TRD. The RD recurrence and PVR rates noted in the 27-gauge patient cohort are congruous with those of published series of 25-, 23-, and 20-gauge vitrectomy with SO, and we do not believe that these complications can be attributed to 27-gauge PPV or 27-gauge SO infusion in our patients [8–11, 37].

A notable finding in our patient cohort was the high percentage of eyes (57 %) that had previously undergone vitrectomy. This is typical for case series of eyes requiring SO, which are more prone to reoperation scenarios. As expected, operative times were longer in eyes where no previous PPV had been performed. This was also the case in our 25-gauge cohort from 2007. Although surgical times for previously vitrectomized eyes were somewhat shorter, removal of vitreous with 27-gauge equipment was efficient and precise, as reported previously, and we do not believe that 27-gauge PPV should be limited to reoperation or that reoperation per se should influence gauge choice [14–18].

As would be expected in any case series of eyes receiving SO, our series included many severely diseased eyes. Mean preoperative and postoperative visual acuity was poor, and a high percentage of eyes involved reoperation. Diabetic medical disease and resulting ischemia was so profound that vision in three eyes deteriorated to NLP, and one patient died during follow-up. Despite NLP vision, these three eyes maintained attached retinas and normal IOP, remained pain-free, and stayed cosmetically normal. Anatomical outcomes were excellent in these eyes, and the NLP vision is not believed to be related to either 27-gauge PPV or 27-gauge SO infusion.

To the best of our knowledge, this series of 21 eyes is the first to report a technique for the safe and efficient placement of SO tamponade in the setting of 27-gauge PPV. Silicone oil injection was easy using the docking technique, and even more optimized designs have already been developed and are on their way to market.

Weaknesses of this study include its small sample size and retrospective nature, thus dramatically limiting the conclusions that can be drawn from our data. Interesting and important questions regarding surgical outcomes and operative times as a function of disease pathology, concurrent combined phacoemulsification, reoperation vs. primary vitrectomy, and SO viscosity are not addressed in this manuscript. Other than reporting that our initial 27-gauge SO experience was qualitatively very similar to our initial (and previously published) 25-gauge SO experience, comparisons between 27-gauge and 25-gauge surgeries based on our data are of very limited utility. We do believe that 27-gauge PPV will continue to enter the mainstream, and we look forward to the results of prospective multi-center randomized clinical trials comparing the outcomes of 23-, 25-, and 27-gauge vitrectomy surgery. We know of at least one such study that is ongoing [38].

Table 3 Comparison of cases of 27-gauge and 25-gauge PPV with SO tamponade

	27-gauge PPV with SO tamponade (n = 21)	25-gauge PPV with SO tamponade (n = 35)	P value
Surgical indication, n (%)			
Tractional retinal detachment	12 (57)	11 (31)	
Retinal detachment	5 (24)	9 (26)	
Vitreous hemorrhage	1 (5)	0	
Endophthalmitis	1 (5)	0	
Macular hole	2 (10)	9 (26)	
Neovascular glaucoma	0	3 (9)	
Giant retinal tear	0	3 (9)	
Mean preoperative BCVA	20/300	20/400	0.2
Mean postoperative BCVA	20/160	20/160	0.9
History of prior PPV, n (%)	12 (57)	16 (46)	0.6
Follow-up (mean ± SD), months	9 ± 6	7 ± 9	0.2
Surgical case time (mean ± SD), min			
All	66 ± 30	80 ± 46 (n = 12)	0.3
Previous PPV	51 ± 25	88 ± 60 (n = 2)	0.1
No previous PPV	85 ± 26	78 ± 46 (n = 10)	0.7
P value (previous vs. no previous PPV)	P < 0.05	P = 0.8	

PPV pars plana vitrectomy, SO silicone oil, BCVA best-corrected visual acuity

In this case series, ICG was used for macular staining in the management of macular membranes. Indocyanine green is considered standard of care in macular surgery in the United States. Although other, less toxic dyes are available and approved for staining in other countries, this is not the case in the United States. Our group has published an exhaustive review of this subject [39].

In conclusion, we propose a possible role for 27-gauge PPV in vitreoretinal diseases where SO infusion is needed. The need for SO tamponade should not be considered a contraindication for 27-gauge surgery. Silicone oil infusion appears to be safe and efficient in the setting of 27-gauge PPV without the need to create larger entry ports. Future study is needed to compare the outcomes of 23-, 25- and, 27-gauge PPV with SO tamponade in the management of complex disease.

Compliance with ethical standards

Funding This work was supported in part by Research to Prevent Blindness, Inc., New York, NY, in the form of an unrestricted research grant to the University of Cincinnati, Department of Ophthalmology. The sponsor had no role in the design or conduct of this research.

Conflict of interest DMM is a consultant to Synergetics USA, Inc. CDR is a consultant to Alcon Laboratories and MedOne Surgical, Inc.

OT and CWM certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; or expert testimony or patent-licensing arrangements) or non-

financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent For this type of study (retrospective study), formal consent is not required. Informed consent for the surgical procedure was obtained from all individual participants.

No identifying information about participants is available in the article.

References

1. Fujii GY, De Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awah C, Ng E, Barnes A, Wu SL, Somerville DN (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. *Ophthalmology* 109:1807–1812
2. Fujii GY, De Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, Kent D (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. *Ophthalmology* 109:1814–1820
3. Lakhnani RR, Humayun MS, de Juan E, Lim JI, Chong LP, Chang TS, Javaheri M, Fujii GY, Barnes AC, Alexandrou TJ (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. *Ophthalmology* 112:817–824
4. Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. *Retina* 25:208–211

5. Kadosono K, Yamakawa T, Uchio E, Yanagi Y, Tamaki Y, Araie M (2006) Comparison of visual function after epiretinal membrane removal by 20-gauge and 25-gauge vitrectomy. *Am J Ophthalmol* 142:513–515
6. Rizzo S, Genovesi-Evert F, Murri S, Belting C, Vento A, Cresti F, Manca ML (2006) 25-gauge, sutureless vitrectomy and standart 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. *Graefes Arch Clin Exp Ophthalmol* 244:472–479
7. Fine HF, Iranmanesh R, Iturralde D, Spaide RF (2007) Outcomes of 77 consecutive cases of 23-gauge transconjunctival vitrectomy surgery for posterior segment disease. *Ophthalmology* 114:1197–1200
8. Siqueira RC, Gil AD, Jorge R (2007) Retinal detachment surgery with silicone oil injection in transconjunctival sutureless 23-gauge vitrectomy. *Arq Bras Oftalmol* 70(6):905–909
9. Narayanan R, Tibra N, Mathai A, Chhablani J, Kuppermann BD (2012) Sutureless 23-gauge versus 20-gauge vitrectomy with silicone oil injection in rhegmatogenous retinal detachment. *Retina* 32(5):1013–1016
10. Riemann CD, Miller DM, Foster RE, Petersen MR (2007) Outcomes of transconjunctival sutureless 25-gauge vitrectomy with silicone oil infusion. *Retina* 27(3):296–303
11. Altan T, Acar N, Kapran Z, Unver YB, Ozdogan S (2008) Transconjunctival 25-gauge sutureless vitrectomy and silicone oil injection in diabetic tractional retinal detachment. *Retina* 28(9):1201–1206
12. Shah CP, Ho AC, Regillo CD, Fineman MS, Vander JF, Brown GC (2008) Short-term outcomes of 25-gauge vitrectomy with silicone oil for repair of complicated retinal detachment. *Retina* 28(5):723–728
13. American Society of Retinal Specialists (2004–2013) Preferences and Trends survey results from 2004–2013. https://www.asrs.org/members/login?returnUrl=%2Fcontent%2Fdocuments%2F_2015-pat-survey-results.pdf. Accessed 23 Apr 2015
14. Oshima Y, Wakabayashi T, Sato T, Ohji M, Tano Y (2010) A 27-gauge instrument system for transconjunctival sutureless microincision vitrectomy surgery. *Ophthalmology* 117:93–102
15. Riemann CD (2011) Initial impressions with 27-gauge vitrectomy. The first generation of a new surgical modality shows promise. *Retina Today Jan/Feb*, pp 85–87
16. Rizzo S, Barca F (2013) Twenty-seven-gauge sutureless microincision vitrectomy surgery: a new frontier. *Retin Today* 8(3):37–40
17. Schaal S, Ozkok A, Nesmith B (2014) 27-gauge vitrectomy surgery: smaller is better. *Retin Today* 9(2):24–32
18. Khan MA, Shahlaee A, Toussaint B, Hsu J, Sivalingam A, Dugel PU, Lakhnani RR, Riemann CD, Berrocal MH, Regillo CD, Ho AC (2016) Outcomes of 27-gauge microincision vitrectomy surgery for posterior segment disease. *Am J Ophthalmol* 161:36–43
19. The Silicone Study Group (1992) Vitrectomy with silicone oil or sulfur hexafluoride gas in eyes with severe proliferative vitreoretinopathy: results of a randomized clinical trial. Silicone study report 1. *Arch Ophthalmol* 110:770–779
20. Abrams WG, Azen SP, McCuen BW, Flynn HW Jr, Lai MY, Ryan SJ (1997) Vitrectomy with silicone oil or long-acting gas in eyes with severe proliferative vitreoretinopathy: results of additional and long-term follow-up. Silicone study report 11. *Arch Ophthalmol* 115:335–344
21. The Silicone Study Group (1992) Vitrectomy with silicone oil or perfluoropropane gas in eyes with severe proliferative vitreoretinopathy: results of a randomized clinical trial. Silicone study report 2. *Arch Ophthalmol* 110:780–792
22. Ibarra MS, Hermel M, Prenner JL, Hassan TS (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. *Am J Ophthalmol* 139(5):831–836
23. Oliveira LB, Reis PA (2007) Silicone oil tamponade in 23-gauge transconjunctival sutureless vitrectomy. *Retina* 27(8):1054–1058
24. Dugel PU, Zhou J, Abulon DJ, Buboltz DC (2012) Tissue attraction associated with 20-gauge, 23-gauge, and enhanced 25-gauge dual-pneumatic vitrectomy probes. *Retina* 32(9):1761–1766
25. Dugel PU, Abulon DJ, Dimalanta R (2015) Comparison of attraction capabilities associated with high-speed, dual-pneumatic vitrectomy probes. *Retina* 35(5):915–920
26. Nagpal M, Wartikar S, Nagpal K (2009) Comparison of clinical outcomes and wound dynamics of sclerotomy ports of 20, 25, and 23 gauge vitrectomy. *Retina* 29(2):225–231
27. Mentens R, Stalmans P (2009) Comparison of postoperative comfort in 20 gauge versus 23 gauge pars plana vitrectomy. *Bull Soc Belge Ophthalmol* 311:5–10
28. Avitabile T, Castiglione F, Bonfiglio V, Castiglione F (2010) Transconjunctival sutureless 25-gauge versus 20-gauge standard vitrectomy: correlation between corneal topography and ultrasound biomicroscopy measurements of sclerotomy sites. *Cornea* 29(1):19–25
29. Hsu J, Chen E, Gupta O, Fineman MS, Garg SJ, Regillo CD (2008) Hypotony after 25-gauge vitrectomy using oblique versus direct cannula insertions in fluid-filled eyes. *Retina* 28(7):937–940
30. Woo SJ, Park KH, Hwang JM, Kim JH, Yu YS, Chung H (2009) Risk factors associated with sclerotomy leakage and postoperative hypotony after 23-gauge transconjunctival sutureless vitrectomy. *Retina* 29(4):456–463
31. Tan HS, Mura M, de Smet MD (2009) Iatrogenic retinal breaks in 25-gauge macular surgery. *Am J Ophthalmol* 148(3):427–430
32. Scott IU, Flynn HW Jr, Dev S, Shaikh S, Mitra RA, Arevalo JF, Kychenthal A, Acar N (2008) Endophthalmitis after 25-gauge and 20-gauge pars plana vitrectomy: incidence and outcomes. *Retina* 28(1):138–142
33. Bamonte G, Mura M, Stevie Tan H (2011) Hypotony after 25-gauge vitrectomy. *Am J Ophthalmol* 151(1):156–160
34. Osawa S, Oshima Y (2014) 27-gauge vitrectomy. *Dev Ophthalmol* 54:54–62
35. Gorovoy IR, Stewart JM (2013) 360° subconjunctival silicone oil after unsutured 23-gauge vitrectomy. *Eye (Lond)* 27(7):894–895
36. El-Batarny AM (2008) Transconjunctival sutureless 23-gauge vitrectomy for vitreoretinal diseases: outcome of 30 consecutive cases. *Middle East Afr J Ophthalmol* 15(3):99–105
37. Scott IU, Flynn HW Jr, Murray TG, Smiddy WE, Davis JL, Feuer WJ (2005) Outcomes of complex retinal detachment repair using 1000- vs 5000-centistoke silicone oil. *Arch Ophthalmol* 123(4):473–478
38. United States Food and Drug Administration (ongoing study) Clinical comparison of 27+® and 23-gauge ULTRAVIT® 7500 Cpm vitrectomy outcomes <https://clinicaltrials.gov/ct2/show?term=27+vitrectomy&rank=1> Accessed 27 Feb 2016
39. Da Mata AP, Riemann CD, Nehemy MB, Foster RE, Petersen MR, Burk SE (2005) Indocyanine green-assisted internal limiting membrane peeling for macular holes to stain or not to stain? *Retina* 25(4):395–404