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ORIGINAL PAPER

Novel and easy techniques for 27-gauge silicone oil infusion and removal

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Abstract

Purpose To introduce novel and easy techniques for 27-gauge silicone oil (SO) infusion and removal.

Methods Consecutive patients treated with 27-gauge pars plana vitrectomy (PPV) plus SO infusion (Infusion Group) and scheduled to have SO removal (Removal Group) were prospectively included, respectively. Patients in Infusion Group underwent 27-gauge PPV plus SO infusion. SO infusion was performed with a 24-gauge intravenous catheter connected with the SO syringe. Patients in Removal Group underwent machine-independent SO removal using a short section of infusion tube connected with a 10-mL syringe. Main outcomes were best-corrected visual acuity, intraocular pressure, surgical time and intra- and postoperative complications.

Results There were thirty-five eyes (35 patients) and forty eyes (40 patients) included in Infusion and Removal Groups, respectively. Mean surgical time of complete SO infusion and removal was 5.5 ± 0.9 and 9.6 ± 2.1 min, respectively. In both groups, no patient experienced postoperative vision deterioration or hypotony. No obvious intra- and postoperative complications were observed.

Conclusions We recommend the use of the 24-gauge catheter method for 27-gauge silicone oil infusion when commercial infusion cannula is unavailable. The machine-independent method using easily available plastic infusion tube and syringe would be an ideal option when 27-gauge surgery is anticipated.

Keywords Infusion · Pars plana vitrectomy · Removal · Silicone oil · 27-Gauge

Introduction

The introduction of 27-gauge vitrectomy systems is one of the remarkable advancements of vitreoretinal surgery in recent years [1–3]. The advantages of 23- and 25-gauge minimally invasive vitrectomy systems (MIVS) have been well documented, including more rapid vision rehabilitation, decreased astigmatism, diminished conjunctival scarring and improved patient comforts [4–8]. However, there were limited reports about the application of 27-gauge MIVS in surgical treatment of cases of high complexity [2, 3, 8, 9]. Consistently, when 25-gauge MIVS was first introduced one decade ago, the initial reports were mainly cases without high complexity. Silicone oil tamponade is usually indicated when the vitreoretinal

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pathology is under complex status, which is one of the obstacles for small-gauge MIVS to be well adopted by vitreoretinal surgeons after its first emergence [2, 10]. Consistent with 25-gauge MIVS, there might be hesitancy or doubt regarding the efficiency of silicone oil infusion using 27-gauge MIVS for its smaller internal diameter and the lack of available silicone oil infusion device [2]. Although there were continuous reports of 27-gauge PPV for more and more vitreoretinal diseases, the method of silicone oil infusion with 27-gauge MIVS has not been well introduced [1–3, 8, 11].

Silicone oil removal is another problem for MIVS to be well accepted by the vitreoretinal surgeons, although surgical paks of 23- and 25-gauge silicone oil removal are now commercially available. However, the silicone oil removal pak raises two problems: First, the pak is machine-dependent and some medical institutions may not be well equipped with the matching vitrectomy platforms; second, the surgical pak may have extra cost to increase economic burden of the patients. To the best of our knowledge, there have not been any reports of silicone oil removal with 27-gauge vitrectomy system [2]. Machine-generated vacuum for silicone oil removal (Alcon's Constellation) is up to 650 mmHg, which is much lower than the positive pressure (about 4000 mmHg) for silicone oil infusion [2]. We could imagine that active removal of SO using 27-gauge trocar cannulas with the current available vitrectomy systems would be of low efficiency, especially for SO of high viscosity. Recently, we reported a machine-independent method for active removal of 5000 centistokes SO with 23-gauge microcannulas and plastic tube [12]. The method is proved to be of low cost and high efficiency, which has been well adapted by vitreoretinal surgeons at some ophthalmic institutions in China [13]. We made some adjustments of the SO removal method using 27-gauge microcannulas to investigate whether it could be further introduced when 27-gauge MIVS was anticipated. Here, we report the novel and easy techniques to have rapid SO infusion and removal with easily available materials in the operation theater.

Methods

The study was approved by the Institutional Review Board of Zhongshan Ophthalmic Center affiliated to Sun Yat-sen University (Guangzhou, China) and performed in accordance with the World Medical Association's Declaration of Helsinki. Patients underwent 27-gauge pars plana vitrectomy (PPV) plus SO infusion (Infusion Group), and those who scheduled to have SO removal (Removal Group) from November 2015 to May 2016 were included, respectively. Inclusion criteria: (1) Infusion Group: patients with retinal detachment, severe proliferative diabetic retinopathy, macular holes and other vitreoretinal diseases for which PPV intervention was needed; 27-gauge PPV was successfully performed without intraoperative change to 23- or 25-gauge ones; high-viscosity silicone oil (5000 centistokes) was judged needed and finally injected into the vitreous cavity. (2) Removal Group: patients with silicone oil tamponade for more than 4 months and those who achieved complete retinal reattachment. Exclusion criteria for both case series: significant opacity of the visual axis caused by diseases of the anterior segment (except for cataract); postoperative follow-up less than 3 months; other serious eye diseases.

All eligible patients underwent comprehensive ophthalmologic examinations during the whole follow-up, including Snellen best-corrected visual acuity (BCVA), non-contact tonometry, slit-lamp microscope, dilated funduscopic examination and assessment of the lens status. Intraoperative details including intraocular pressure fluctuation, presence of sclerotomy fluid leakage, necessity of sclerotomy suturing and total surgical time were recorded.

All the surgeries were performed under retrobulbar anesthesia by an experienced surgeon (S.Z.) at Zhongshan Ophthalmic Center of Sun Yat-sen University, Guangzhou, China. Written informed consent was obtained from each patient.

Surgical technique of 27-gauge PPV plus silicone oil infusion

Standard 3-port 27-gauge PPV (27+ Total Plus Pak; Constellation Vitrectomy System, Alcon Laboratories, Fort Worth, TX). All the three cannulas were inserted 3.0–4.0 mm posterior to the limbus in a curved manner. The infusion cannulas were located in the inferotemporal quadrant. Another two cannulas were, respectively, located in the superotemporal and superonasal quadrants. Using wide-angle viewing systems (Volk Optical, Inc., Mentor, OH and Carl

Zeiss Meditec AG, Jena, Germany), the core and peripheral vitreous were firstly cut off using a cutting rate of 7500 cuts per minute (cpm) with linear aspiration of 0–650 mmHg.

After intravitreous manipulations including vitreous removal, epiretinal membrane peeling, endolaser photocoagulation retinopexy and air/fluid exchange were completed, viscous fluid control pak (reference number 8065750957, Constellation Vision System, Alcon Laboratories, Fort Worth, TX) was used for SO (Oxane® 5700; Bausch & Lomb, Rochester, NY, US) infusion through the 27-gauge microcannulas at the superior quadrants.(The silicone oil syringe was held by the surgeon's right hand.) After the removal of the internal metal needle, a commercially available 24-gauge intravenous catheter (Supercath® 5, reference number SP120-24-19-W, Togo Medikit Co., Ltd., Miyazaki, Japan or Vasofix®, reference number 4269071S-03, B. Braun Melsungen AG, Melsungen, Germany) was connected to the nipple of the SO syringe (Fig. 1a). The SO syringe was loaded onto the viscous fluid injection system of the vitrectomy machine. The tip of the catheter was cut off to be about 2–3 mm with a 45° bevel at the end (Fig. 1b). Positive pressure for SO infusion was set to 80 psi throughout the procedure. The beveled tip of the catheter was easy to dock into the 27-gauge cannula for SO infusion without obvious leakage (Fig. 1c, d). The air-infusion pressure was firstly set to 15 mmHg and was decreased to 10 mmHg once SO tamponade was about 1/2 of the vitreous cavity. When SO tamponade was nearly completed, the air-infusion tube was removed from the inferotemporal cannula. At the conclusion of the surgery, all the three cannulas were removed. The above conjunctiva was pressed with cotton swab to prevent sclerotomy leakage. (Details are demonstrated in Supplementary video.)

Surgical technique of 27-gauge silicone oil removal

The surgical technique of 27-gauge SO removal is identical with our previously published study [12]. The maximal vacuum generated by the 10-mL syringe could be easily higher than 650 mmHg (Fig. 2a). The vacuum generated by the 10-mL syringe was estimated about 1400 mmHg once the plunger was lifted up to the top. It could be summarized as follows: (1) insertion of the 27-gauge trocar cannulas at the superotemporal and inferotemporal quadrants about 3.0–4.0 mm to the limbus; (2) connection of fluid infusion tube to the inferotemporal cannula to generate an infusion pressure of about 30 mmHg with balanced saline solution; (3) removal of the valve of the superotemporal cannula; (4) a commonly used plastic infusion tube was connected with the nipple of a 10-mL syringe with a distal end about 3 mm; (5) attachment of the short infusion tube to the conjunctiva surface and covering of the microcannula inside; (6) the core plunger was lifted manually and then fixed up by a vessel clamp snapping the handle's inferior part, to generate a suction power on the silicone oil (Fig. 2b); (7) slight indentation of the sclera with a squint hook to drive the oil bubble to the superotemporal cannula once the oil/fluid surface was visible through the pupil; (8) usage of a flute needle to capture small oil bubbles in the vitreous cavity when necessary; (9) thorough checkup of the fundus and having necessary intravitreous manipulations; (10) withdrawal of cannulas and checking for sclerotomy leakage; pressing the above conjunctiva with cotton swab. (Details are demonstrated in Supplementary video.)

Postoperative follow-ups and statistical analysis

Follow-up examinations were scheduled at 1 day, 1 week, 1 month and 3 months after the surgery for both case series. All Snellen visual acuity values were converted to the logarithm of the minimum angle of resolution (logMAR) for statistical analysis. Visual acuity of light perception (LP) was assigned as 2.9, hand movements (HM) as 2.6, and counting fingers (CF) as 2.3. Postoperative vision improvement was defined as a postoperative gain of two or more than two Snellen lines of visual acuity, or a postoperative change of ambulatory vision to no less than Snellen 20/400. All data were analyzed using the SPSS 19.0 statistical software (SPSS Inc., Chicago, IL, USA). Paired t test and Mann–Whitney test were used as appropriate. All the continuous data were expressed as mean ± standard deviation (SD). P values < 0.05 were considered statistically significant.

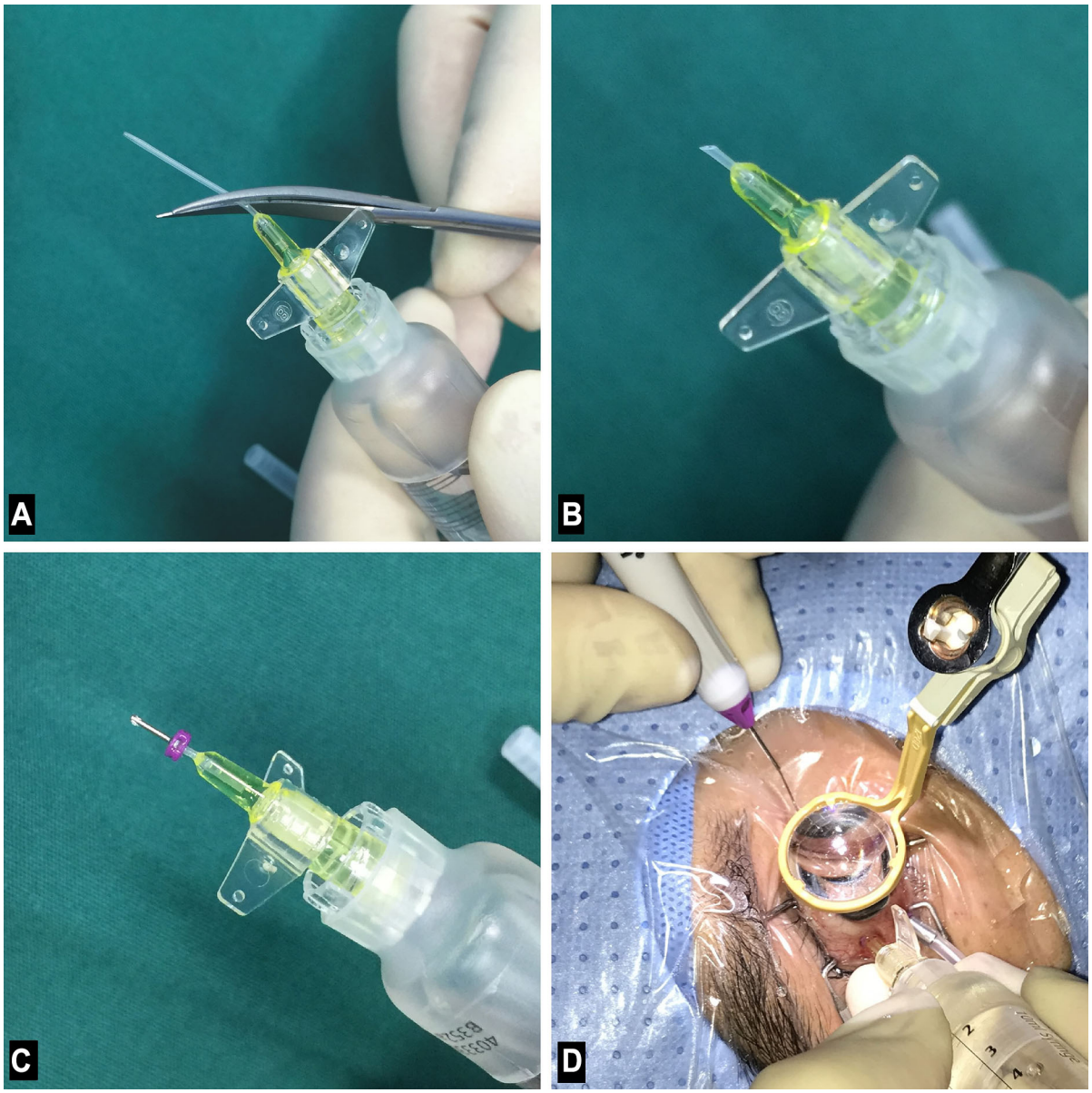

Fig. 1 27-Gauge silicone oil infusion. **a** A 24-gauge intravenous catheter is connected to the nipple of the silicone oil syringe; **b** the tip of the catheter was cut off to be about 2–3 mm with a 45° bevel at the end; **c** the beveled tip of the catheter is easy to dock into the 27-gauge cannula for silicone oil infusion; **d** silicone oil infusion is performed with one-handed manner

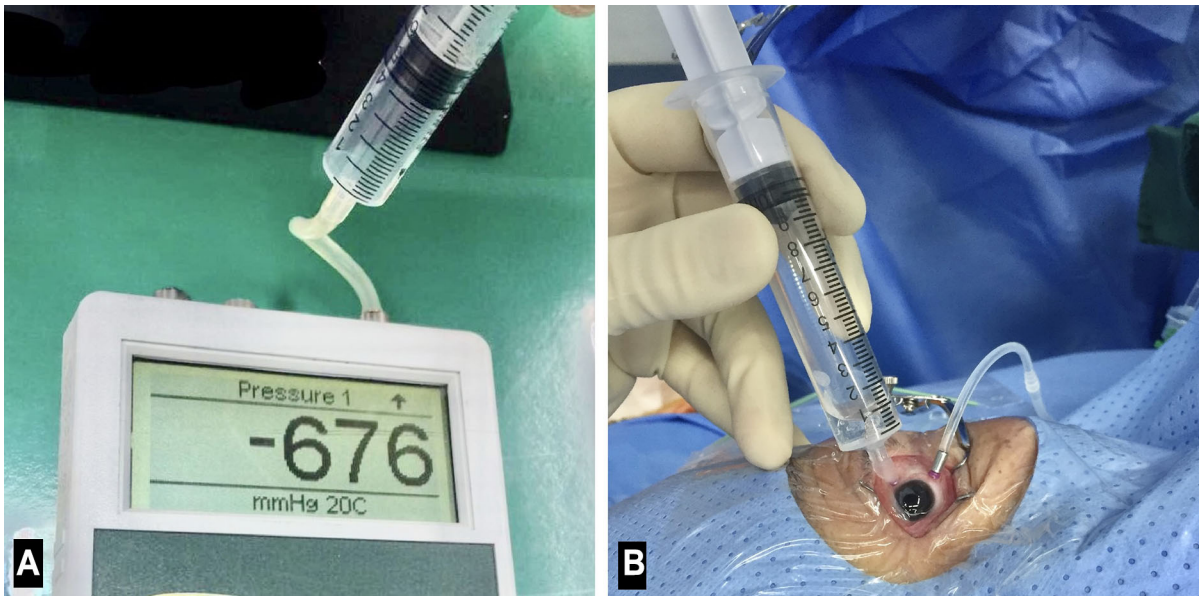

Fig. 2 27-Gauge silicone oil removal. **a** The vacuum generated by the 10-mL syringe when the plunger is lifted up to 4.5 mL measures 676 mmHg; the real vacuum (estimated about 1400 mmHg) generated by the 10-mL syringe when the plunger was lifted up to the top could not be measured, because it was out of the measurement's upper limit of the vacuometer (DMP-2200, BC Group International Inc. St. Charles, MO); **b** attach the short infusion tube to the conjunctiva surface and cover the microcannula inside, and the core plunger is lifted manually and fixed up by a vessel clamp snapping the handle's inferior part, to generate a suction power on the silicone oil

Results

Case series of 27-gauge PPV plus silicone oil infusion

Patient demographics

Thirty-five eyes of 35 patients (21 males and 14 females) were included, with mean age 42.5 ± 15.4 years (range 14–73 years). Mean follow-up duration after surgery was 5.7 ± 1.1 months (range 3–8 months). Surgical indications for 27-gauge PPV plus SO infusion were primary rhegmatogenous retinal detachment (14 eyes), proliferative diabetic retinopathy (16 eyes), highly myopic retinal detachment associated with macular hole (3 eyes), acute retinal necrosis (1 eye) and traumatic retinal detachment (1 eye). Mean preoperative logMAR BCVA was 1.47 ± 0.63 (range 0.70–2.90, Snellen equivalent HM-20/100).

Surgical outcomes

One day after surgery, mean logMAR BCVA was 1.55 ± 0.54 (range 1.00–2.60, Snellen equivalent HM-20/200), without statistically significant difference with the preoperative one ($P > 0.05$). Mean logMAR BCVA at the final follow-up was 0.78 ± 0.39 (range 0.10–1.70, Snellen equivalent 20/1000-20/25), with statistically significant difference with the preoperative one ($P < 0.001$). No eyes experienced vision deterioration in the follow-ups. Mean total surgical time of PPV and silicone oil infusion was 47.5 ± 13.2 min (range 34–96 min). Mean time of silicone oil infusion was 5.5 ± 0.9 min (range 4.0–7.5 min). Mean preoperative intraocular pressure (IOP) was 11.3 ± 3.8 mmHg (range 6–23 mmHg).

Adverse events

During silicone oil infusion, eye wall collapse/hypotony or highly elevated IOP (which would be alerted by the vitrectomy machine once happened) was not observed in any eyes; and no obvious leakage of SO

was observed at the site of catheter–cannula connection. At the conclusion of the surgery, sclerotomy suturing was needed in three (8.6%) eyes to prevent obvious leakage of silicone oil. It was unnecessary to use forceps to form back pressure in order to hold the cannula in place.

On the first day after surgery, mean IOP was 21.8 ± 7.8 mmHg (range 11–41 mmHg); elevated IOP (> 21 mmHg) was observed in 15 (42.9%) eyes. Patients with elevated IOP were treated with topical antiglaucoma eye drops with/without corneal paracentesis, and 11 of them restored normal IOP at the week 1 postoperative follow-up. At the month 1 follow-up, elevated IOP was observed in eight (22.9%) eyes, three of which were associated with iris neovascularization secondary to diabetic retinopathy. At the month 3 follow-up, four eyes without success of IOP decreasing to normal were scheduled to have silicone oil removal, followed by anti-vascular endothelial growth factor (anti-VEGF) injection. At the final follow-up, 26 eyes remained silicone oil-tamponaded without any silicone oil-related complications, with mean IOP of 16.9 ± 6.3 mmHg (range 8–36 mmHg). There were three eyes (all had undergone silicone oil removal) with elevated IOP and failure of medical control at the final follow-up and were referred to the glaucoma department for further therapy. In all the follow-ups, no eyes experienced hypotony (< 5 mmHg) or SO leakage from the initial sclerotomies.

Case series of 27-gauge silicone oil removal

Patient demographics

Forty eyes of 40 consecutive patients (25 males and 15 females) who were scheduled to have SO (Oxane® 5700; Bausch & Lomb, Rochester, NY, US) were prospectively included, with mean age of 49.4 ± 15.9 years (range 15–77 years).

Surgical outcomes

Silicone oil could be completely removed in all the eyes with the current method. Mean total surgical time was 41.8 ± 17.2 min (range 20–75 min). Mean SO removal amount was 4.5 ± 0.8 mL (range 3.5–6.5 mL). Mean time for complete SO removal was 9.6 ± 2.1 min (range 6.5–15 min), which was positively correlated with silicone oil removal amount ($r = 0.844$, $P < 0.001$) (Fig. 3). Intraoperatively, flute needle and squint hook were additionally introduced to help completely remove SO in 26 eyes. Photocoagulation plus intraocular lens and epiretinal membrane peeling were performed in 18 and 5 eyes, respectively.

Adverse events

During the surgical procedure, no eyes experienced eye wall collapse or suddenly decreased IOP. After withdrawing the cannulas, no obvious sclerotomy leakage was observed, and thus no eye needed suturing. The plastic infusion tube did not cause obvious conjunctival and scleral wound or scar when we observed at the conclusion of and after surgery. No other intraoperative complications were observed. After surgery, no cases experienced visual acuity deterioration or refractory hypotony in all the follow-ups. No significant residual oil bubbles were observed in the anterior chamber or in the fundus. There was no retinal redetachment occurred throughout the follow-ups.

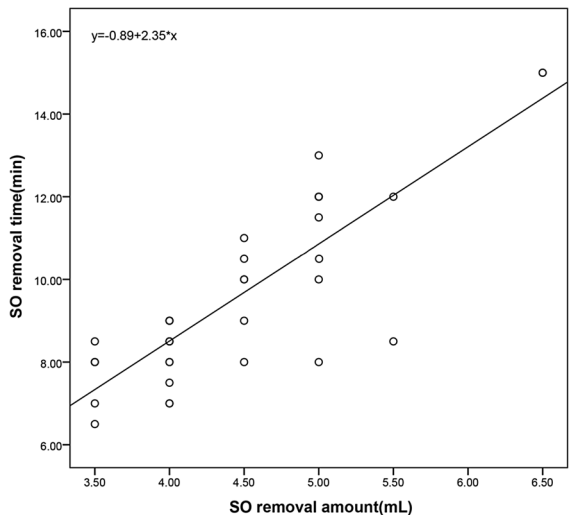

Fig. 3 Mean time for complete silicone oil removal is positively correlated with silicone oil removal amount ($r = 0.844$, $P < 0.001$)

Discussion

To the best of our knowledge, the current report is the first to have detailed description of 27-gauge SO infusion and removal. In theory, the high efficacy of the current methods can be well explained with the Hagan–Poiseuille law (volume flow rate (Q) = $\Delta P\pi d^4/L8n$; ΔP = pressure difference between ends, d = diameter of the tube, L = length of the tube, n = viscosity). Obviously in the current methods, the length of tube for SO injection/drainage was shortened at the most without narrowing of the internal diameter. Recent report by Toygar et al. [2] suggested that it was feasible to have 27-gauge PPV in conjunction with SO infusion without the need to have alteration of sclerotomy enlargement for silicone oil infusion. The method described by Toygar et al. [2] was creative but not all the same as the current one, although 24-gauge intravenous catheter (Becton-Dickinso) was used in some of the patients. Differently, the current method used one-handed manner to infuse silicone oil without the need of forceps to hold the cannula in place to form back pressure, and all the eyes underwent infusion of 5000 centistoke silicone oil. The underlying factors might contribute to the tight connection of the tip of the cannula with the beveled tip of the catheter and good compliance of the catheter.

Since January 2016, 27-gauge viscous fluid infusion cannula has been commercially available (reference number 3273, MedOne Surgical, Inc., Sarasota, Florida, USA), so one-handed manner of silicone oil infusion with 27-gauge vitrectomy system is now not a challenge for some vitreoretinal surgeons if their institutions can be equipped with the infusion cannula [2, 14]. However, 27-gauge vitrectomy has been performed in more and more districts and institutions; we could not neglect the fact that the 27-gauge infusion cannula (MedOne) is not easily available for many vitreoretinal surgeons in other areas of the world. (According to personal communications, no main ophthalmic institutions in China have purchased the MedOne infusion cannula.) Therefore, the current method might be the feasible choice to overcome the difficulty of 27-gauge silicone oil infusion that some vitreoretinal surgeons are now facing, as 24-gauge intravenous catheter would be more easily available in many hospitals. The mean time duration of SO infusion using the current method was 5.5 ± 0.9 min (range 4.0–7.5 min), which was comparable with that when MedOne infusion cannula was used (5000 centistoke oil injection time was approximately 3–5 min) [14]. We summarized the following advantages of the current method: tight connection without leakage when having SO infusion; rapid infusion; intraoperative IOP remained stable when having SO infusion; easy availability of the material; and low cost. (The catheter was about 6 dollars in China.) Disadvantages of the current method include the following: It might not be as convenient as the MedOne infusion cannula and connection of the catheter with 27-gauge cannula might not be as completely matching as the MedOne infusion cannula. Nonetheless, the current report indicates that the necessity of SO placement and/or unavailability of the MedOne infusion cannula is not the contraindications of 27-gauge vitrectomy for some selected cases.

Repeated literature searching identified that the current method is the first to report rapid removal of SO (5000 centistokes) with 27-gauge cannulas. Recently, we reported a machine-independent method to have active removal of 5000 centistokes SO with 23-gauge cannulas and plastic infusion tube, with mean time of 4.54 ± 0.78 min (range 3.0–6.0 min) [12]. Consistently, the current methods proved high efficacy and safety when 27-gauge cannulas were used. Mean time of SO removal was 9.6 ± 2.1 min (range 6.5–15 min), twice of the 23-gauge method. As known to us, SO removal with 27-gauge cannulas was considered more difficult when compared with SO infusion, because of limited automated vacuum generated by the vitrectomy machine (e.g., maximum vacuum of the Alcon's Constellation is only 650 mmHg). According to the Hagan–Poiseuille law mentioned above, we are able to learn that machine-generated vacuum is not great enough for effective removal of high-viscosity SO through 27-gauge cannula, smaller internal diameter of which generates much greater friction when silicone oil is running inside.

According to the Hagan–Poiseuille law, at a given tube length (the length of 27-gauge microcannula), given diameter (the internal diameter of 27-gauge microcannula is 0.4 mm) and given viscosity (the viscosity of SO in the current methods is 5000 centistokes), the only way to improve efficacy of SO removal is increasing the suction vacuum. Vacuum generated by the 10-mL syringe measured over 650 mmHg when the plunger was lifted to the top,

which offers greater suction force for silicone oil drainage with 27-gauge cannulas than the vitrectomy platform does. Although the plastic adapter of the current method is part of the Alcon 23- and 25-gauge silicone oil removal pak (reference number 8065750957, Viscous Fluid Control Pak, Alcon Laboratories, Fort Worth, TX), one remarkable advantage of the machine-independent method is larger vacuum. Actually, we recommended the use of commercially available silicone oil removal pak when 23- and 25-gauge vitrectomy platforms were used, because of its higher convenience. However, there has not been any 27-gauge silicone oil removal pak available for us; the current method might be a good option when 27-gauge SO removal is anticipated for less conjunctival wounding and postoperative discomforts. Other advantages of the current method include the following: the materials are ready for most vitreoretinal surgeons; it is easy to assemble; it is not difficult to learn and perform; it is of low cost; and it provides higher vacuum if necessary. Disadvantages might include the possibility of conjunctival wounding (it was not observed in the current study) and not enough gas-tightness of the connection between the conjunctiva surface and the plastic tube. (It is affected by the surgeon's proficiency, flexibility of the conjunctiva and transverse section of the plastic tube.)

Limitations of the current study included small sample size and short postoperative follow-ups. The stability of the plastic materials was not tested thoroughly with some objective parameters, and further work is warranted to have in-depth study. The MedOne infusion cannula was unavailable for us when we conducted the current study; so pitifully, we were unable to have a comparison group to have better analysis of the data. We are convinced that 27-gauge PPV will gradually cover a wider range of vitreoretinal diseases, and silicone oil infusion would not be considered a challenge by many vitreoretinal surgeons. Although there was not any 27-gauge silicone oil removal pak available in the market, we could imagine that the technical problem would be well solved sooner.

In conclusion, we recommend the use of the 24-gauge catheter method to have 27-gauge silicone oil infusion when commercially available infusion cannula is unavailable. Until the future introduction of well-designed silicone oil removal pak, the current machine-independent method using easily available plastic infusion tube and syringe would be an ideal option when 27-gauge surgery is anticipated.

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Compliance with ethical standards

Conflict of interest All the authors declare there are no competing financial interests in relation to the current study.

Ethical approval All procedures performed in the 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 Informed consent was obtained from all individual participants included in the study.

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