• Clinical Research •

Multiple imaging modalities in intraocular silicone oil emulsification and its related complications

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Abstract

● **AIM:** To elucidate the manifestations and associated complications observed in patients with intraocular silicone oil (SO) emulsification through multiple imaging modalities.

● **METHODS:** This single-center, observational, retrospective study included 116 patients who underwent pars plana vitrectomy (PPV) with SO injection for retinal detachment (RD), followed by subsequent SO removal at the Second Hospital of Hebei Medical University from January 2013 to January 2023. Comprehensive records of ophthalmic examinations utilizing multiple imaging techniques were maintained.

● **RESULTS:** The study comprised 56 females and 60 males, with a mean age of 52.75±13.6y. The mean follow-up duration for SO tamponade was 9.04±11.33mo (range: 1-84mo). Among the participants, 59 patients were diagnosed with SO emulsification, while 57 patients were in the SO unemulsified group. Patients with SO emulsification had a significantly prolonged SO tamponade duration (P<0.01). Multiple imaging techniques revealed notable signs of SO emulsification and its complications, such as 4 cases (3.4%) with posterior corneal SO-like keratic precipitates (KP) observed by anterior segment photography, 23 cases (19.8%) exhibiting spherical high-reflection signals in the inter-retina, retinal pigment epithelium, or choroid detected by Spectralis spectral domain optical coherence tomography (SD-OCT), 4 cases (3.4%) showing slow movement of emulsified SO droplets within retinal vessels during fluorescein angiography (FFA), plain and enhanced head magnetic resonance imaging (MRI) images of these four patients did not detect emulsified SO in the lateral ventricles, suprasellar cistern, subarachnoid space, third ventricle, fourth ventricle, or other intracranial locations.

● **CONCLUSION:** Intraocular emulsified SO can lead to damage in both anterior and posterior segment tissues, encompassing corneal degeneration, cataracts, glaucoma, retinal and choroid inflammation. Objective multiple imaging techniques such as anterior segment photography, SD-OCT, FFA, and MRI offer comprehensive evaluation and diagnosis of SO emulsification and its associated complications.

● **KEYWORDS:** silicone oil emulsification; multiple imaging techniques; Spectralis spectral domain optical coherence tomography; fluorescein angiography; magnetic resonance imaging

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INTRODUCTION

Silicone oil (SO), introduced by Cibis *et al*[1] in the 1960s, has now emerged as the preferred choice for cases at high risk of complex retinal detachmen caused by proliferative vitreoretinopathy (PVR), proliferative diabetic retinopathy (PDR), and ocular trauma due to its favorable optical transparency, biocompatibility, and chemical inertness. Despite advancements in technology and the development of new intraocular tamponades, SO remains an ideal and currently irreplaceable option for intraocular use. However, prolonged intraocular retention of SO can lead to emulsification. This process involves the formation of small oil droplets at the interface between SO and intraocular fluids, which can subsequently separate from the large oil bubble in the vitreous cavity and disperse into ocular tissues[2].

SO emulsification is influenced by various factors, including the physicochemical properties of SO, surgical techniques, duration of SO retention, and patient-specific factors such as age, gender, and the underlying cause of retinal detachment (RD)[3-4]. Understanding the mechanisms and factors

contributing to SO emulsification is crucial for mitigating its occurrence. Emulsified SO can directly impact adjacent ocular tissues and cause various complications due to its migration, including secondary glaucoma, band keratopathy, cataract formation, and retinal inflammation, affecting both the anterior and posterior segments of the eye. Additionally, emulsified SO may migrate migration into the optic nerve, orbit, or intracranial space, leading to severe adverse reactions[5-10].

Clinically, the diagnosis of SO emulsification is typically limited to direct observation methods such as slit-lamp examination or indirect ophthalmoscopy. These techniques primarily detect severe emulsification but do not clearly define the relationship between emulsified SO and the retina or retinal vasculature. This study utilized multiple imaging techniques including fluorescein angiography (FFA), optical coherence tomography (OCT) and others to comprehensively observe and analyze the imaging characteristics of emulsified SO in the living retina and retinal vasculature. By elucidating the interactions between emulsified SO and the retina, optic nerve, and other intraocular tissues, this study aims to establish the optimal timing for SO removal to prevent toxic effects on these structures.

PARTICIPANTS AND METHODS

Ethical Approval The study received approval from the Institutional Review Board of the Second Hospital of Hebei Medical University (2020-R468) and adhered to the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants.

Participants and Main Measurements This was a single-center, observational, retrospective study. Subjects included were those who underwent primary standard three-port, 23-gauge pars plana vitrectomy (PPV) with SO injection for RD, followed by subsequent SO removal, at the Second Hospital of Hebei Medical University from January 2013 to January 2023. Exclusion criteria encompassed patients with prior SO injection, history of intraocular surgery other than PPV or cataract extraction, and elevated intraocular pressure (IOP>21 mm Hg) preceding the initial PPV. Comprehensive records of ophthalmic examinations utilizing multiple imaging techniques were maintained. These assessments included best-corrected visual acuity [BCVA, logarithm of the minimum angle of resolution (logMAR)], slit-lamp biomicroscopy, dilated fundus examination with indirect ophthalmoscopy, IOP measurement *via* non-contact tonometry, OCT, FFA and enhanced magnetic resonance imaging (MRI). Data were collected at pre-PPV surgery and pre-SO removal stages. Based on findings from multiple imaging modalities prior to SO removal, participants were categorized into SO emulsification and SO unemulsification groups.

Surgical Procedure Preoperatively, 0.5% tropicamide compound was administered to achieve adequate mydriasis. All participants underwent standard three-port 23-gauge PPV using the Alcon Constellation system (Alcon Laboratories, Inc., Fort Worth, TX, USA), performed by the same experienced surgeon. After central vitreous removal, triamcinolone acetonide was injected to aid in visualizing the residual posterior hyaloid, which was then excised. Depending on the retinal conditions, additional procedures such as membrane peeling, relaxing retinotomy, and inferior peripheral iridectomy were performed. Subsequently, after fluid-air exchange and endophotocoagulation, SO with a viscosity of 5700 cSt (Bausch & Lomb Inc., Rochester, NY, USA) was injected. All participants also underwent SO removal surgery by the same surgeon. During the SO removal procedure, three fluid-air exchanges were performed to aspirate any residual emulsified SO particles from the eye. A peripheral retinal examination was conducted during partial fluid-air exchange. For patients presenting with emulsified SO in the anterior chamber, anterior chamber irrigation was performed to eliminate these particles.

Anterior Segment Imaging and Fundus Exam Procedure Slit-lamp biomicroscopy (IS-400, TOPCON, Tokyo, Japan) was employed to evaluate the anterior segment. Following dilation with 0.5% compound tropicamide, a detailed examination of the SO tamponade and fundus status was conducted using an indirect ophthalmoscope (Ra-200, Beijing, China). This examination documented the distribution and morphological features of emulsified SO and its relationship with surrounding tissues. Observations included retinal repositioning, macular conditions, SO status, and the presence of epiretinal or subretinal membranes and tractional RD. The anterior segment camera (SR-52, TOPCON, Tokyo, Japan) captured images by ensuring perpendicular alignment between the instrument lens and the corneal surface of the subjects. Several characteristic complications associated with SO emulsification were meticulously observed and documented, including emulsified SO-like keratic precipitates (KP) on the posterior corneal surface, emulsified SO in the anterior chamber, and emulsified SO particles on the iris surface. High-quality images were selected for subsequent storage and analysis.

Fundus Photography and Fluorescein Angiography Procedure All patients underwent fundus photography and fluorescein angiography (FFA), both performed by the same experienced technician. Following mydriasis with 0.5% compound tropicamide, color fundus photographs (CFP) were captured using a Nonmyd7 camera (Kowa, Nagoya, Japan). Subsequently, an intravenous injection of 5 mL of 10% sodium fluorescein (Alcon, USA) was administered. Early-phase (10-20s) to late-phase (10min) fluorescein angiography was conducted using the Heidelberg Spectralis system (HRA,

Table 1 Demographic characteristics and ophthalmic parameters for patients with SO emulsification and unemulsification group

Parameters	SO emulsification group (*n*=59)	SO unemulsification group (*n*=57)	Statistics	*P*
Age, y	50.47±14.4	55.11±12.41	-1.857	0.066
Sex (female/male)	29/30	27/30	4.11E-05	0.995
Duration of SO tamponade, mo	13.92±14.31	4±0.88	5.313	1.76E-06
Accompanied ocular conditions, *n* (%)			18.57	0.069
AMD	0	1 (0.008)		
PCV	1 (0.008)	0		
BRVO	1 (0.008)	0		
CRVO	0	1 (0.008)		
CRVO/VH	0	1 (0.008)		
ERM	0	1 (0.008)		
MH	9 (0.078)	7 (0.06)		
PDR	7 (0.06)	9 (0.078)		
RRD	28 (0.241)	35 (0.302)		
Uveitis	1 (0.008)	0		
Ocular trauma	12 (0.103)	1 (0.008)		
VH	0	1 (0.008)		
pre-PPV vision	1.32±0.4	1.25±0.42	-1.005	0.317
pre-SO removal vision	1.2±0.41	1.06±0.41	1.849	0.067
pre-PPV IOP	14.45±3.67	14.67±3.74	0.321	0.749
pre-SO removal IOP	20.02±7.18	17.64±5.75	1.968	0.052

SO: Silicone oil; AMD: Age-related macular degeneration; PCV: Polypoidal choroidal vasculopathy; BRVO: Branch retinal vein occlusion; CRVO: Central retinal vein occlusion; VH: Vitreous hemorrhage; ERM: Epiretinal membrane; MH: Macular hole; PDR: Proliferative diabetic retinopathy; RRD: Rhegmatogenous retinal detachment; PPV: Pars plana vitrectomy; IOP: Intraocular pressure.

Heidelberg Engineering, Germany) to obtain and analyze characteristic images.

Spectral-Domain OCT Imaging Procedure Retinal imaging was conducted using a Spectralis spectral domain optical coherence tomography (SD-OCT; Heidelberg Engineering, Heidelberg, Germany) scanner. Subjects positioned their chins on the rest, ensuring perpendicular alignment with the corneal surface. A skilled technician performed all scans and reviewed each image post-acquisition to identify and correct any motion artifacts or segmentation errors, repeating the examination if necessary. Horizontal or vertical scans were performed over retinal areas with significant emulsified SO particle accumulation, as observed during indirect ophthalmoscopy and fundus photography. Scan lengths ranged from 6 mm to 8 mm with a scan line spacing of 0.24 mm to obtain high-quality OCT images. These images were then used for detailed measurement and analysis of retinal layer structures. The follow-up mode was employed during examinations of revisit patients to facilitate comparative analysis with previous lesion sites.

Statistical Methods Data analysis was conducted using SPSS version 25.0 (IBM, Chicago, IL, USA). Descriptive statistics for general patient characteristics and various examination parameters were expressed as mean±standard deviation (SD). The Snellen BCVA was converted to the logMAR equivalent for statistical analysis, light perception (LP) at 2.6 logMAR, hand movements (HM) at 2.3 logMAR, and counting fingers (CF) at 1.85 logMAR. Differences in the prevalence of ocular findings (continuous variables) between the two groups were compared using a two-sided Student's *t*-test. Categorical variables were analyzed using the Chi-square test. A *P*-value less than 0.05 was considered statistically significant, and a *P*-value less than 0.01 was considered highly statistically significant.

RESULTS

Demographic Characteristics and Ophthalmic Parameters This study included 116 eyes from 116 patients, comprising 56 females and 60 males, with a mean age of 52.75±13.6y (range 14-74y). The mean follow-up duration for SO tamponade was 9.04±11.33mo (range: 1-84mo). Of the participants, 59 patients (29 females, 30 males) were diagnosed with SO emulsification, while 57 patients (27 females, 30 males) were in the SO unemulsified group (Table 1). The mean age was 50.47±14.4y in the SO emulsification group and 55.11±12.41y in the SO unemulsified group. There were no significant differences between the groups in terms of age or gender (*P*=0.066 and *P*=0.995, respectively). Patients with SO emulsification had a significantly longer duration of SO tamponade (*P*=1.76E-06). No differences were observed in associated ocular conditions, pre-PPV vision, pre-SO removal vision, pre-PPV IOP, or pre-SO removal IOP between the two groups. The data analysis results are presented in Table 1.

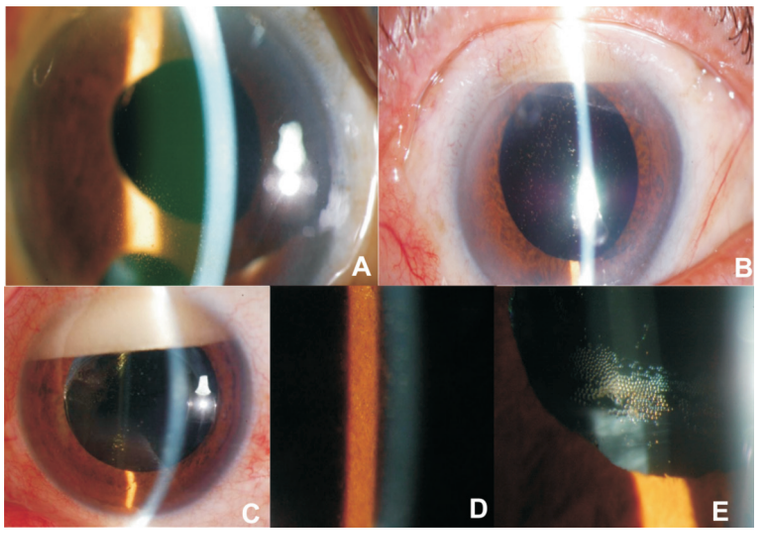

Figure 1 Anterior segment imaging features of SO emulsification and its complications A-B: Posterior corneal SO-like KP were depicted, marked by small brown dots located near the pupil area; C: A liquid plane of emulsified SO particles occupied approximately one-quarter to one-third of the upper anterior chamber, adhering closely to the corneal endothelium and making contact with the iris surface; D: Numerous emulsified SO particles were observed on the iris surface, either as individual entities or clustered in the iridocorneal angle, protruding into the anterior chamber; E: Transparent, bead-like emulsified SO particles were seen densely adhering to the surfaces of intraocular lenses and capsular membranes. KP: Keratic precipitates, SO: Silicone oil.

Anterior Segment Imaging Features of SO Emulsification and its Complications Eleven patients (9.5%) exhibited emulsified SO in the anterior chamber, of these, 9 (7.8%) were pseudophakic and 2 (1.7%) were aphakic. Four patients (3.4%) presented with posterior corneal SO-like KP, characterized by small brown dots near the pupil area (Figure 1A-1B). In two patients (1.7%), a liquid plane of emulsified SO particles occupied about 1/4 to 1/3 of the upper anterior chamber, closely adhering to the corneal endothelium and contacting the iris surface (Figure 1C). Four patients (3.4%) showed numerous emulsified SO particles on the iris surface, either individually or clustered in the iridocorneal angle, protruding into the anterior chamber (Figure 1D). Additionally, three patients (2.6%) had transparent bead-like emulsified SO particles densely adhering to the surfaces of intraocular lenses and capsular membranes (Figure 1E). SO emulsification-associated corneal degeneration was also observed in four patients (3.4%).

Fundus Signs of SO Emulsification The indirect ophthalmoscopy examinations of 59 patients with SO emulsification revealed no retinal hemorrhage or exudation, proliferative changes in the anterior or subretinal retina, or tractional RD. Retinal repositioning was noted to be well-performed. Among these patients, 16 (13.8%) showed inadequate SO tamponade, characterized by an SO-water interface occupying the lower 1/4 to 1/3 of the vitreous cavity. Emulsified SO was notably clustered horizontally near this interface, exceeding 3 pixel distance (PD). In patients lacking an SO-water interface, emulsified SO appeared in strip clusters along the superior or inferior vascular arcades (Figure 2A) or diffusely surrounding the optic disc (Figure 2B). Additionally, emulsified SO particles were observed along retinal arterioles and venules, accumulating in areas larger than 2 PD. CFP depicted multiple transparent droplet-like emulsified SO particles arranged in clusters (Figure 2A) or lines (Figure 2B) along the retinal vasculature or near the lower SO-intraocular fluid interface.

OCT Changes of SO Emulsification In SD-OCT imaging, emulsified SO particles manifested as high-density spherical reflectance signals. Among 19 patients (16.4%) with anterior segment emulsified SO particles, OCT identified single or multiple high-density spherical reflectance signals at various retinal layers, potentially involving the macular region. Emulsified SO particles appeared as single-layer formations anterior to the retina (Figure 3A-3B), or accumulated within a fluid-filled space between the central fovea and the boundary of the SO, presenting as dense punctate high-reflection signals on OCT, forming small patchy areas of high reflection anterior to the retina (Figure 3C). In 2 patients (1.7%), emulsified SO particles were observed surrounding and within the optic nerve, appearing as punctate high-reflection signals. Numerous dot-like high-density reflection signals were also evident in cross-sectional scans of the optic nerve (Figure 3D), corresponding to locations of emulsified SO particles observed on CFP. Among 17 patients (14.7%), emulsified SO particles were detected between retinal layers as small spherical high-reflection signals, visible in the outer plexiform layer, outer nuclear layer (Figure 3E), nerve fiber layer (Figure 3F), and retinal pigment epithelium (Figure 3G). Additionally,

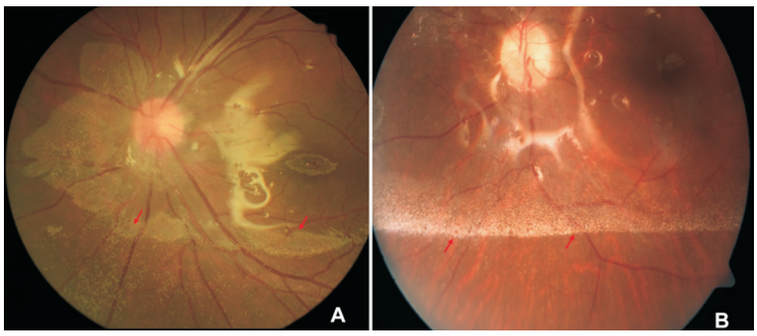

Figure 2 Fundus signs of SO emulsification A: CFP showing multiple transparent droplet-like emulsified SO particles arranged in clusters along the retinal vasculature; B: CFP illustrating emulsified SO particles arranged in lines near the lower SO-intraocular fluid interface. CFP: Color fundus photographs, SO: Silicone oil.

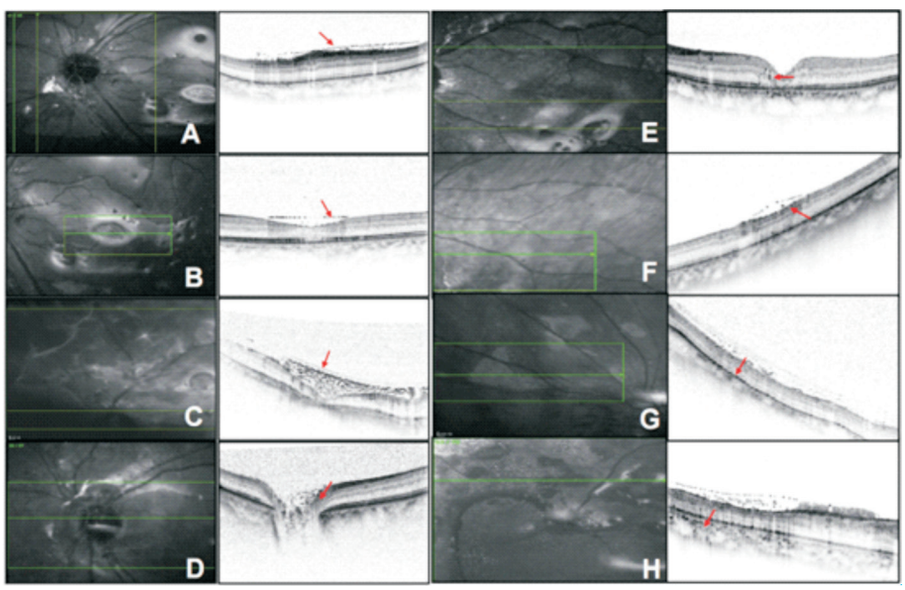

Figure 3 OCT changes of SO emulsification A-B: Emulsified SO particles were observed as single-layer formations anterior to the retina; C: Emulsified SO particles accumulate within a fluid-filled space between the central fovea and the boundary of the SO, appearing as dense, punctate high-reflection signals on OCT, forming small patchy areas of high reflection anterior to the retina; D: Emulsified SO particles were seen surrounding and within the optic nerve, manifesting as punctate high-reflection signals. Numerous dot-like high-density reflection signals were also evident in cross-sectional scans of the optic nerve; E: Emulsified SO particles were detected between retinal layers as small spherical high-reflection signals, visible in the outer plexiform layer and outer nuclear layer; F: Emulsified SO particles were visible in the nerve fiber layer; G: Emulsified SO particles were detected within the retinal pigment epithelium; H: Additionally, emulsified SO particles were noted in the choroid. OCT: Optical coherence tomography; SO: Silicone oil.

emulsified SO particles were noted in the choroid of 6 patients (5.2%; Figure 3H).

FFA Findings of SO Emulsification In FFA imaging, all 59 patients exhibited multiple transparent droplet-like emulsified SO particles arranged in clusters or elongated patches along the retinal vasculature or near the interface formed between the lower SO and intraocular fluid (Figure 4). Among these, eight patients (6.9%) showed multiple spherical high-fluorescence particles within retinal vessels during FFA, appearing early in angiography and remaining visible throughout, with decreased fluorescence in later stages (Figure 4A). The locations of these spherical high-fluorescence particles corresponded to those of emulsified SO observed near retinal vessels on fundus photography. Among these cases, four (3.4%) demonstrated slow movement of emulsified SO droplets within retinal vessels during FFA, characterized by small spherical high-fluorescence particles moving with the flow of angiography and showing noticeable displacement in later stages (Figure 4B). FFA examination did not reveal emulsified SO droplets invading the optic nerve in any of the 59 patients. Enhanced MRI scanning of the head in the four patients suspected of emulsified SO particle movement within retinal vessels did not detect emulsified SO or other abnormal density particles or masses in the lateral ventricles, suprasellar cistern, subarachnoid space, third ventricle, fourth ventricle, or other intracranial locations.

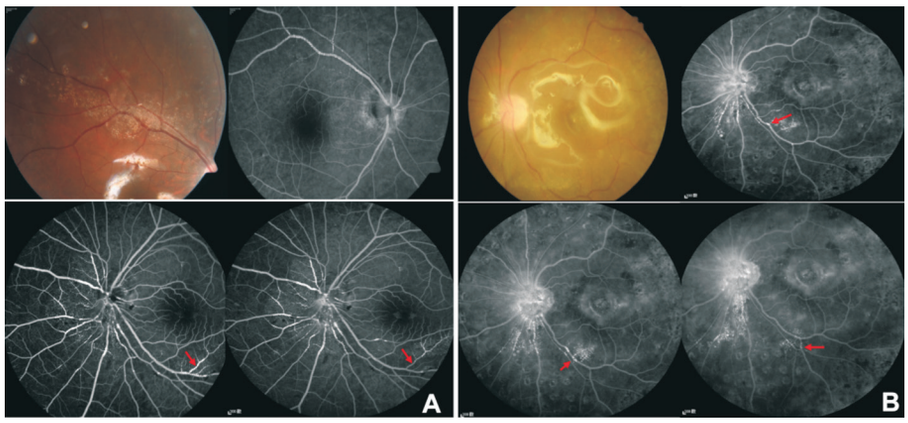

Figure 4 FFA findings of SO emulsification A: Multiple spherical high-fluorescence particles were observed within retinal vessels during FFA. These particles appeared early in the angiographic sequence and remain visible throughout, with decreased fluorescence in the later stages. B: Slow movement of emulsified SO droplets within retinal vessels was demonstrated during FFA, characterized by small spherical high-fluorescence particles that move with the flow of angiography, showing noticeable displacement in the later stages. FFA: Fluorescein angiography; SO: Silicone oil.

DISCUSSION

Medical-grade SO is employed as a high-quality intraocular tamponade for managing various complex retinal detachments, owing to its exceptional optical transparency, biocompatibility, and surface tension properties[11]. However, SO is prone to emulsification, which is influenced by several factors including the brand of SO used, timing of filling, patient age, underlying pathologies, presence of concurrent inflammatory responses, intraoperative conditions (such as steroid use, concomitant photocoagulation, or cryocoagulation), concurrent surgeries, and crystalline lens status[3-4]. Consistent with previous reports, our study found that patients with SO emulsification had a significantly longer duration of SO tamponade (P=1.76E-06). This supports the conventional belief that SO should be removed between 4 to 6mo post-filling[12-14].

Large SO bubbles can fragment into smaller droplets, dispersing into various ocular tissues such as the iris, ciliary body, trabecular meshwork, and retina, potentially causing inflammation and other complications[15-18]. Clinically, the diagnosis of SO emulsification is typically limited to direct observation methods such as slit-lamp examination or indirect ophthalmoscopy. These techniques primarily detect severe emulsification but do not clearly define the relationship between emulsified SO and the retina or retinal vasculature. Objective multiple imaging techniques such as OCT, FFA, and MRI can provide comprehensive evaluation and diagnosis for SO emulsification and its complications. In our observations of patients with SO emulsification, SD-OCT revealed SO droplets located epi-, intra-, and subretinally, appearing as single or clustered high-density dot-like or small globular reflectivity signals, potentially involving the macular region while preserving normal retinal architecture. SD-OCT allowed for the precise delineation of SO droplets within retinal layers and their relationship with surrounding retinal structures. Similar findings were reported by Chung and Spaide[19] in 2003 using first-generation OCT technology to detect emulsified SO in a patient following macular hole repair combined with internal limiting membrane peeling, prompting timely SO removal upon detection, with subsequent OCT follow-up revealing diminishing intra-retinal SO voids over time. Ererra *et al*[20] conducted a retrospective analysis in 2013 using OCT to identify high reflectivity spherical microparticles of emulsified SO in various intraretinal, subretinal, and epiretinal locations among 11 patients undergoing SO filling for PVR. Their findings further substantiated that these interlaminar high reflectivity signals are indeed emulsified SO droplets. Odrobina and Laudańska-Olszewska[21] in 2014 similarly demonstrated through a retrospective study that SD-OCT imaging showed high reflectivity signal particles of emulsified SO between the optic nerve and retinal layers in 24 patients treated with SO filling for PVR. Our study corroborated these findings, showing that emulsified SO presents as high reflectivity signals detected epi-, intra-, and subretinally. This validates OCT as an effective means to detect SO emulsification.

During the FFA examination of 59 patients with SO emulsification, we observed the slow movement of emulsified SO droplets along retinal vessels in 4 cases. This was manifested as multiple small spherical high-fluorescence particles in retinal veins or arteries. These high-fluorescence particles observed in FFA corresponded morphologically-in terms of distribution, shape, extent, and location-with the surface distribution of emulsified SO seen in fundus photography. Furthermore, considering that FFA primarily delineates retinal vasculature and assesses blood circulation status, and acknowledging that normal retinal vasculature does not contain granular substances, the high-fluorescence

particles observed in FFA are highly likely to be emulsified SO droplets within retinal blood vessels. High-density OCT scans were also conducted on regions identified with dense high-fluorescence particles in FFA to obtain a visual representation of the emulsified SO droplets in retinal blood vessels. However, the current highest resolution SD-OCT scan cannot visualize the microstructural images of retinal vessel cross-sections and is unable to confirm the existence of high-density reflective signals within retinal vessels. As emulsified SO droplets travel within retinal vessels, regions exhibiting high-fluorescence density particles in FFA may coincide with areas where these droplets have already passed during the OCT examination. Consequently, this movement hinders the acquisition of reliable evidence confirming that the high-fluorescence particles observed in angiography are indeed emulsified SO droplets. In the ophthalmic examination of these 4 cases, emulsified SO distribution was found around retinal vessels, consistent with previous pathological studies[22] indicating that macrophages engulfed emulsified SO droplets around retinal vessels and possibly entered retinal vessels, suggesting that the emulsified SO droplets enter retinal vessels through phagocytosis by macrophages.

Previous studies have documented the infiltration of emulsified SO into intracranial regions, including the third and fourth ventricles as well as the lateral ventricles within the nervous system[7,23-26]. Common risk factors associated with this phenomenon include congenital optic disc anomalies and elevated IOP in patients. It remains a possibility that emulsified SO enters the brain through alternative routes, such as the circulation of macrophage vesicles that have engulfed SO, or *via* retrograde flow through orbital veins followed by filtration into the subarachnoid space of cerebrospinal fluid[22]. Although plain and enhanced head MRI images of four cases suspected of emulsified SO entry into retinal vessels did not reveal emulsified SO or other abnormal density particles or masses in the nervous system, evidence of suspicious emulsified SO droplets was found in the optic nerve cross-section (*via* SD-OCT) and retinal blood vessels *in vivo* (*via* FFA). This provides critical evidence for the migration of emulsified SO into ocular tissues and various systemic organs, and opens new avenues for studying the mechanisms by which emulsified SO droplets enter the nervous system. In clinical practice, we do not advocate the routine use of FFA or MRI in all patients with SO tamponade. Instead, these advanced imaging modalities are selectively employed based on specific clinical indications. Typically, slit-lamp biomicroscopy, fundus imaging, and OCT serve as the primary tools for screening and monitoring SO-filled eyes, as they are non-invasive, cost-effective, and sufficient for diagnosing most SO-related complications. However, in cases where these routine examinations reveal ambiguous or concerning findings, such as suspected retinal ischemia, neovascularization, or emulsified SO particles were detected between retinal layers or optic nerve, we proceed with FFA or MRI to obtain further diagnostic clarity. FFA is particularly valuable for evaluating SO migration into retinal vessels, while MRI is reserved for rare but serious complications, such as SO migration into the optic nerve, orbit, or intracranial space. This selective approach ensures that the use of invasive and expensive imaging modalities is both clinically justified and cost-effective, while optimizing patient outcomes.

Several limitations should be noted in interpreting the findings of this study. First, while meticulous OCT scans of emulsified SO areas observed in fundus photography revealed high-density spherical particles, and corresponding FFA examinations identified high-fluorescence dots along retinal vessels with movement during angiography, anterior OCT scans confirmed these as emulsified SO droplets[27]. However, pathology has not definitively confirmed that the high-fluorescence dots in FFA are emulsified SO droplets, necessitating future animal experiments or pathological examination of removed SO emulsified eyes for verification. Second, the origin and movement of high-fluorescence particles in FFA remain uncertain, whether due to SO entering retinal vessels and migrating into the vitreous cavity through inflammatory vascular leakage or through staining after passing the blood-retinal barrier and adhering to vessel walls. Further research, including animal experiments, is essential to clarify these mechanisms. Lastly, our study did not comprehensively evaluate visual function in patients with emulsified SO between retinal layers, nor conducted long-term follow-up after SO removal surgery.

In conclusion, this study employed multiple imaging techniques to comprehensively scan and analyze emulsified SO at specific anatomical sites, which provided precise assessments of the distribution of emulsified SO within retinal layers and perivascular regions. Early detection of complications linked to SO emulsification facilitates prompt removal of intraocular emulsified SO, thus preventing potential damage to the retinas, optic nerves, and other intraocular structures. Moreover, for patients without detected complications from SO emulsification, extending the SO tamponade duration under strict regular monitoring may enhance conditions favorable for retinal reattachment, thus potentially lowering the recurrence rate of RD.

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investigation; project administration; resources; supervision; visualization; and revision.

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