

In Vivo Emulsification Analysis of 1000 cs and 5000 cs Silicone Oil after Rhegmatogenous Retinal Detachment Vitrectomy Surgery

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Abstract

Purpose: To compare *in vivo* emulsification of silicone oil 1000 and 5000 centistokes (cs) after retinal detachment surgery. **Design:** Comparative non-interventional Retrospective study. **Methods:** Silicone oils from patients who underwent retinal detachment surgery were investigated using Spectrophotometer UV-Vis. Spectroscopically changes determine emulsification with the time of tamponade, inflammation, patients age and severity of retinal detachment. **Results:** We found significant difference on absorbance ($p = 0.004$) between used 1000 Centi stoke (cs) silicon oil (average wave length 2.51 nm; SD: 1.575 nm) and used 5000 cs silicon oil (average wave length 0.910 nm; SD: 0.564 nm). **Conclusions:** *In vivo* emulsification was higher in silicone oil 1000 compared to 5000 cs silicone oil after vitreoretinal tamponade 8 - 12 weeks due to retinal detachment surgery. Emulsification related to higher absorbance and lower transmittance in 1000 cs silicone oil. Inflammation may become a factor affecting this condition.

Keywords

Silicone Oil, Spectrophotometry, Emulsification

1. Introduction

Silicone oils were used in retinal detachment surgery since 1962 and had been used increasingly especially in complicated cases such as retinal detachment with severe proliferative vitreoretinopathy, giant retinal tears, proliferative diabetic retinopathy, viral retinitis and ocular trauma [1].

Emulsification is the most common complication in silicone oil tamponade [2]. It can lead to clinical problems such as glaucoma, keratopathy, and cataract

formation [3]. Emulsification can be identified as droplet formation of a small bubble of silicone oil with or without opacification of the bubble. Time formation of emulsification was different from one person to another. Several authors investigated various factors which can increase the occurrence of emulsification. Inflammation, blood constituent, protein, lipid, and viscosity were identified as factors that can influence the stability of silicone oil in human eyes [2] [4] [5].

The most common used silicone oil in vitreoretinal surgery is 1000 and 5000 centi Stoke (cs). Silicone oil with viscosity 1000 cs is easier and faster to inject and remove but has limitation sooner to be emulsified compared to higher viscosity. Silicone oil 5000 cs has lower tendency to emulsify which may provide longer tamponade effect [6] [7]. However, study showed that the 5000 cs silicone oil may be associated with a poorer anatomic and visual outcome compared with 1000 cs silicone oil [8].

Although *in vitro* study showed that silicone oil with higher viscosity was more stable than lower viscosity, Soheilian *et al.* found that clinically, there was no difference in complications rates between 1000 vs. 5000 cs silicone oil after retinal detachment surgery [6].

The purpose of this study was to compare *in vivo* emulsification of silicone oil 1000 and 5000 cs after retinal detachment surgery.

2. Methods

This study non-randomized comparative study to 13 silicone oil 1000 cSt and nine silicone oil 5000 cs was taken from patients who underwent silicon oil tamponade for 8 - 12 weeks tamponade duration. The inclusions criteria are patient with primary vitrectomy due to Rhegmatogenous Retinal Detachment (RRD) who underwent vitrectomy with silicon oil endo tamponade. The exclusion criteria are combined endo tamponade with perfluorocarbon liquid; using perfluorocarbon liquid during vitrectomy surgery; patient using steroid or anti-inflammation therapy at least three months prior the surgery. All patients had undergone retinal detachment surgery at Cicendo Eye Hospital, Indonesia. Removal of silicone oil tamponade decision was based on the attachment of retina within 8 - 12 weeks of tamponade. The silicon oil removal was done by a single operator using vitrectomy machine (Alcon Constellation Vision System, Fort Worth Texas USA). As the normal control, we compared the samples with unused 1000 and 5000 cSt silicone oil from the same brand.

To perform Silicone oil evaluation, the samples were placed in an acrylic cuvet with dimension 4.5 cm × 1.425 cm × 1.425 cm and 1.5 cc volume. The Spectrophotometry UV-Vis T70+ (PG Instruments Ltd) was used to evaluate absorbance and transmittance changes in both groups. Assessment of silicon oil emulsification macroscopically was done by a single operator using criteria 'fish egg' appearance on silicon oil samples. The examiner was blinded to study subject. No interventions were given in this study. The statistical analysis was performed using Shapiro-Wilk test and Mann-Whitney test with $p \leq 0.05$ is consi-

dered as significant.

3. Result

We collected 13 samples from the eye that tamponade using 1000 cs silicon oil and nine samples from the eye that using 5000 cs oil. Detail of the clinical characteristics is shown in **Table 1** and **Table 2**. The age range of patients on 100 cs silicon oil group was between 31 - 64 years. Respectively, 29 - 41 years range on 5000 cs group. There is statistically significant on patient's age between the two group ($p = 0.043$).

Duration of tamponade on the two groups is between 8 - 12 weeks with average 9.9 weeks in group 1, and 10.6 weeks in group 2. There is no statistical difference between the two group on tamponade duration ($p = 0.202$).

Table 3 showed the clinical characteristic of retinal detachment related to silicon oil emulsification in each group. This showed that 1000 cs silicon oil has a tendency to emulsified compare to 5000 cs.. There is no emulsification macroscopically on 5000 cs silicon oil found.

Table 4 and **Table 5** showed the comparison of changes in absorbance that measure the emulsification of silicon 1000 cs and 5000 cs using spectrophotometry. On this result, the absorbance of 1000 cs silicon oil is higher than 5000 cs. There is statistically significant different in absorbance between two groups ($p < 0.005$). This finding shows that in general 1000 cs silicon oil is easier to emulsified comparing to 5000 cs silicon oil.

4. Discussion

Silicone oil is an important and widely used intravitreal tamponade in vitreoretinal

Table 1. Clinical Characteristics of Patients with 1000 cs Tamponade of Silicone Oil.

No	Age (years)	Sex	Diagnose	Time of Tamponade (weeks)
1	40	M	RD + PVR grade B + Aphakia	12
2	64	M	RD + PVR grade B	12
3	39	F	RD (3 quadrants)	8
4	47	F	Total RD + SenileCataract	8
5	48	M	RD	9
6	50	F	RD	12
7	31	M	Total RD + Traumatic cataract	12
8	47	M	GRT	8
9	61	M	RD	8
10	45	F	RD (3 quadrants)	12
11	50	M	RD	12
12	47	M	RD + PVR	8
13	64	M	Total RD	8

Table 2. Clinical Characteristics of Patients with 5000 cs Tamponade of Silicone Oil.

No	Age (years)	Sex	Diagnosis	Time of Tamponade (weeks)
1	39	M	Total RD	12
2	38	M	RD (3 quadrants)	12
3	30	M	RD	8
4	29	M	RD	8
5	58	M	RD + Coloboma of Choroid	12
6	33	M	RD (2 quadrants)	12
7	40	M	Total RD	12
8	36	M	Total RD + PVR grade D	8
9	62	F	Total RD	12

*RD = Retinal Detachments, PVR = Proliferative vitreoretinopathy, GRT = Giant Retinal Tears.

Table 3. Patient Characteristic Related to Silicon Oil Emulsification.

Patients Characteristics	Tamponade of Silicone Oil			
	1000 cs (n = 13)		5000 cs (n = 9)	
	Emulsification (+)	Emulsification (-)	Emulsification (+)	Emulsification (-)
1) Sex				
Male	4	5	0	8
Female	3	1	0	1
2) Retinal Detachment (RD)				
Total RD	2	0	0	4
RD	0	1	0	2
RD with PVR	1	1	0	0
GRT	1	0	0	0
Total RD + History of Trauma	1	0	0	0
3) Age (years)				
<40	3	0	0	7
>40	4	6	0	2
4) Time of Tamponade (weeks)				
<10 weeks	4	3	0	3
>10 weeks	5	1	0	6

*RD = Retinal Detachments, PVR = Proliferative vitreoretinopathy, GRT = Giant Retinal Tears.

surgery that is intended as a temporary tamponade for rhegmatogenous retinal detachment surgery. Based on the viscosity, there are several types of silicone oil that are used in vitreoretinal surgery. Selection of the type of silicone oil used is based on the patient's clinical condition and estimated the duration of tamponade needed [2].

Table 4. The Comparison of Absorbance Changes in Silicon Oil 1000 cs and 5000 cs Sample to unused Silicon Oil 1000 cs and 5000 cs.

Absorbance	Group	
	Silicon Oil 1300 cs (n = 13)	Silicon Oil 5500 cs (n = 9)
Wave length:		
770 nm	0.059	0.111
Mean (SD)	0.148 (0.093)	0.103 (0.062)
Median	0.131	0.096
Range	0.049 - 0.357	0.024 - 0.176
Comparison of Wave length sample to unused silicon oil	p = 0.005	p = 0.699

Table 5. The Comparison of Absorbance Changes in Silicon Oil 1000 cSt and 5000 cSt Samples.

Absorbance	Group		p-value
	Silicon Oil 1300 cs (n = 13)	Silicon Oil 5500 cs (n = 9)	
Wave length:			
770 nm			
Mean (SD)	2.51 (1.575)	0.910 (0.564)	0.004
Median	2.22	0.86	
Range	0.83 - 6.05	0.21 - 1.58	

The 1000 cs and 5000 cs silicon oil are the two type of silicon oil most used in vitreoretinal surgery. The 1000 cSt silicone oils are easier to inject and remove from the eye but have less stable properties resulting in more frequent complications. Silicon 5000 cs oil has more stable properties when compared with 1000 cs silicone oil but is more difficult to inject and removal due to its viscosity [9].

Several factors are thought to affect changes in physical properties of silicone oils in the eyeballs such as the rheological properties of silicone oil itself, the saccadic movement of the eyes and the patient's head, the length of tamponade, and the presence of blood and inflammation components in the vitreous cavity [10].

Table 3 shows the age characteristics in both groups are slightly different. Age on a 5000 cs group is younger compared 1000 cs group. There are 7 of 9 samples from patients aged ≤ 40 years, but the changes in absorbance (emulsification) that occur in this group is lower. In the group of 1000 cs silicone oil, three samples from patients aged ≤ 40 years, which all have absorbance value (degree of emulsification) higher when compared to 5000 cs silicone oil in the same age group.

The presence of inflammatory cells released in the retinal detachment can diffuse into the silicone oil [11]. This condition will cause the silicone oil absorb more surfactants that lead the damage of silicon oil structure [12]. Examination

using spectrophotometer to damaged silicon oil showed increase in absorbance value due to the silicon oil absorb various surfactants.. This increase in absorbance value is the initial parameter of changes in silicone oil which in the later stages can lead to emulsification [13].

Silicone oil is widely used in surgery are trimethyl siloxy-terminated vitreoretinal SiO, poly-trifluoro propyl-methylsiloxane (FsiO) and the most rarely used polyphenylmethylsiloxane [2]. In this study, we used only one type of silicone oil. Therefore, the silicone oil used in this study has the same rheological properties.

Vitreous samples examination of PVR patients showed an increased number of cytokines, such as interleukin-1 beta (IL-1 β), TNF- α , and monocyte chemoattractant protein-1 (MCP-1). Study showed, growth factors, such as basic fibroblast Growth Factor (bFGF) in PVR patient is also higher when compared with patients with macular holes or idiopathic premacular fibrosis [14]. Some studies suggest that the macrophage will release enzyme on PVR resulting in vitreous structure changes as a result of the protein matrix proteolysis and also the formation of fibrotic membranes to synthesis the fibroblast growth factor by macrophages [15].

As a result, on the 1000 cs group showed a considerable increase in absorbance values (emulsification rates) in some samples taken from patients with rhegmatogenous retinal detachment with PVR, giant retinal tear, and total retinal detachment (samples 1, 4, 7, 8, 10, 13). Samples in the 5000 cs silicone oil group with retinal detachments, total retinal detachment and retinal detachment with PVR have increased absorbance value (emulsified). However, the increasing of absorbance value in the 5000 cs sample group did not exceed the absorbance value Silicone oil in the sample group 1000 cs. This suggests that with a risk factor of an inflammatory condition, 5000 cs silicone oil has a more stable properties compared with 1000 cs silicone oil.

Bleeding factor is one of the factors that can accelerate the silicone oil emulsification [4] [16]. Bleeding components that have a tendency to cause emulsification based on *in vitro* studies are including fibrin, fibrinogen, serum, plasma, γ -globulin, and lymphocytes. Study showed that *in vitro* study the serum causes a slightly higher emulsification of silicone oil when compared with plasma [17]. In this study, we have no data the relation of bleeding factors to the emulsification.

In this study the duration of tamponade in the two sample groups varied, ranging from 8 - 12 weeks on based on the patient clinical conditions. Tamponade on 1000 cs silicone oil samples performed over eight weeks resulted in higher absorbance values when compared to the 5000 cs sample group. Increased absorbance values in the 5000 cs sample group who had tamponade over eight weeks is not higher when compared to the 1000 cs sample group at the same tamponade duration.

The duration of tamponade is one of the factors that influence the damage of

silicone oil [18]. Several previous studies mentioned that the longer the tamponade, the possibility for emulsification will be greater. Damage to silicone oil is caused because the longer the silicone oil is inside the eyeball, the more surfactants are absorbed by the silicone oil. This will lead to an increase in the absorbance value of silicone oil. Silicone oils that have absorbed various surfactants will be more easily broken down into small molecules resulting in decreased surface tension, buoyancy and viscosity decrease. In the advanced stages of this damaged silicone oil, it is easier to migrate to the anterior segment of the eyeball or subretinal space and cause further complications [19].

Emulsification of silicone oil in the eyeball is also affected by the movement of the eyeball and the movement speed of silicone oil against the walls of the vitreous cavity. As the eye moves, the silicone oil inside the ball will also move [20]. However, this movement also depends on the viscosity of the silicone oil, the intensity of movement of the eyeball and the head; and the frequency of movement itself. Low viscosity silicone oil will have a fairly high/fast motion gradient, while silicone oil with a higher viscosity will have a slower gradient. Until recently, there is no study report the effect of the eye and head movement on emulsification, but some *in vitro* studies suggest that the mechanical energy imparted to silicone oil will cause the breakdown of the surface tension of silicone oil to dissipate silicon oil into small particles which are unstable. These tiny particles are easier to absorb the organic molecules present in the eyeball. In this study, the movement of the eyeball and the patient's head can be estimated by the duration of tamponade. The longer the tamponade in the patient's eyeballs, the possibility of eye movement and the head of the patient will also affect more damage to the silicone oil [10].

Factors that may affect damage to silicone oils such as the saccadic movement of the eyeball and the patient's head, the duration of tamponade and the presence of surfactants in the eyeballs are affected each other [10]. In addition to these factors, the characteristics of silicone oil also affect the damage of silicone oil. Higher viscosity silicone oils have more stable properties because they have stronger, stronger polymer bonding chains when compared to silicone oils with lower viscosity. This polymer bonding chain will limit the absorption of surfactants into silicone oil. The diffusion of the surfactant into silicone oil depends on the size of the molecule, the bond between the molecules and the nature of the molecule itself. In this study, there was an increase in absorbance (damage to silicone oil) in both groups that could be caused by the presence of inflammatory factors and the type of silicone oil used.

Absorbance 1000 cs silicon oil is greater when compared with 5000 cs silicone oil. Even though macroscopically there is no sign of silicone oil damage, but microscopically the physical and chemical structures changes may already there. This is evident from the increase in absorbance in both groups of samples with a larger increase occurring in the 1000 cs silicone oil sample group.

The inflammation and blood properties were not assessed in this study. This is

considered as the limitation of this study. Further study involving more samples is suggested to confirm findings in this study.

5. Conclusion

Silicon oil with 5000 cs viscosity has better emulsification stability in tamponade to retinal detachment surgery comparing to 1000 cs Silicon oil. Although there was no emulsification of silicone oil clinically, there were some structural changes occurring in silicone oil which was higher in silicone oil 1000 cs compared to 5000 cs.

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