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Dynamics of the Macular Hole-Silicone Oil Tamponade Interface with Patient Positioning as Imaged by Spectral Domain Optical Coherence Tomography

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Abstract

Purpose—To evaluate with spectral domain optical coherence tomography (SD-OCT) the relationship between the retina and overlying silicone oil tamponade after macular hole surgery, and to evaluate how this relationship changes with patient positioning.

Patients and Methods—Retrospective consecutive case series of 10 eyes from 9 patients who underwent macular hole surgery with silicone oil tamponade and subsequent SD-OCT scans. Four of the included eyes were also imaged with patients in face-down posture to determine if the silicone-retina apposition changes with prone positioning. Finally, a single patient was additionally scanned in the lateral and supine positions.

Results—The posterior surface of the silicone oil bubble was well visualized in all 10 eyes. In the majority of eyes (7/10) the oil tamponade bridged across the macular hole creating a pre-foveal fluid space, but in 3 eyes the silicone oil filled the macular hole and was seen in touch with the underlying foveal depression or retinal pigment epithelium. In 75% of eyes (3/4) the silicone oil-retinal approximation did not vary with face-down position. Supine positioning clearly floated the silicone tamponade anteriorly and off of the retinal surface.

Conclusions—Silicone oil tamponade can either bridge across macular holes, or in a novel finding, can fill the underlying foveal depression or macular hole space. Generally, the oil position is stable between face-forward and prone SD-OCT images, suggesting that either of these patient positions allows waterproofing of the underlying macular hole. Finally, our images confirm that supine positioning should be avoided post-operatively as it leads to loss of oil-retinal tamponade.

Keywords

Spectral domain OCT; Macular Hole; Silicone Oil

Introduction

Since the introduction of vitrectomy for macular holes,¹ surgical success rates for hole closure and vision improvement are reported at close to 90%.² One carefully studied component of

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successful surgery is proper tamponade of the macular hole after vitrectomy.³ While common practice is tamponade with intra-ocular gas and face-down positioning post-operatively,⁴ silicone oil tamponade can also be used safely and effectively.^{5,6} Although some evidence suggests that C3F8 gas provides a higher hole closure rate and better final visual acuity,⁷ silicone oil may be advantageous due to increased freedom from positioning in patients who are unable, or unwilling, to maintain face-down posture post-operatively or in patients who must travel at altitude post-operatively. Additionally, a report of silicone oil use for re-operations after failed macular hole surgery with gas showed at least anatomical success with hole closure in more than half of cases.⁸

Silicone oil, like intraocular gas, likely works by isolating the macular hole from liquid in the vitreous cavity,⁹ and evidence supports that a complete oil fill of the vitreous cavity is an important factor in surgical success.⁵ Presumably, this is because the silicone oil tamponade physically “waterproofs” the macular hole and isolates it from fluid in the vitreous space. The use of optical coherence tomography (OCT) in oil filled eyes after macular hole surgery allows quality images of macular hole morphology and can help monitor post-operative hole closure,¹⁰ but very few studies have focused specifically on the silicone oil-retinal interface. The case series available use time domain OCT to show that silicone oil “bridges” across macular holes, or the foveal depression, creating a small pre-foveal fluid filled space between the lowest point of the retinal depression and the silicone oil bubble in all patients studied.^{11,12} However, these reports do not address how the silicone oil-retinal approximation changed with positioning.

We used spectral domain OCT (SD-OCT) to study silicone oil tamponade in post-operative macular hole patients. Our goal was to determine the silicone oil-retinal configuration after macular hole surgery, and to study the effects of positioning on this relationship.

Methods

With University of California at San Diego institutional review board approval, we performed a retrospective consecutive cases series of patients who underwent standard 3-port vitrectomy for macular hole surgery with 5000 centistoke (cs) silicone oil tamponade (except patient 6 who had 1000cs silicone oil) and subsequent post-operative SD-OCT evaluation. 10 eyes from 9 patients treated between November 2006 and March 2009 were included, and all data were collected in a de-identified fashion.

Spectral domain OCT images were taken with one of two machines. From November 2006 through March 2008 the Spectral OCT/SLO (OCT SLO, Software version 1.66, Opko Instrumentation/OTI, a division of OPKO Health, Miami, Florida) was available at The Jacobs Retina Center and was used for the first 5 patients in this study. From April 2008 through the remainder of the retrospective study the Heidelberg Spectralis (HRA+OCT, Heidelberg Instruments, Vista, CA) was available and used to image post-operative macular hole patients including study patients 6 through 9. As an inter-machine comparison, patient 9 was also imaged with the OPKO-OTI. The Spectralis was used for all positioning studies because the camera head can be dismounted to capture images in varied position.

All images were acquired in patients who were seated face-forward in a “standard” OCT position unless otherwise indicated in the text or figures. Additional face-down images were obtained by dismounting the Spectralis camera and setting it lens-upward on the Spectralis table with the patient seated and bent forward with their forehead on the chin-rest. A single patient (patient number 7) was unable to co-operate with positioning even briefly for imaging. A single patient (patient 6, left eye) was also imaged lying on her side and in face-up position on a stretcher.

We attempted a similar protocol on four post-operative macular hole patients with C3F8 gas tamponade. In only a single patient (patient 9) could reliable images be captured in either the face-forward or face-down position. This patient was 8 days post-operative after macular hole surgery with C3F8 gas, and images captured were far clearer in the face-down than face-forward position.

Results

This study included 10 eyes from 9 patients who underwent macular hole surgery with silicone oil tamponade (Table 1). Ages ranged from 58 to 78 years old, and all had idiopathic macular holes with no history of trauma. Four patients received silicone oil tamponade after failing surgery with intra-ocular gas previously, and five patients had primary silicone oil because of positioning or travel constraints.

In all silicone oil patients studied, the silicone-fluid interface was identified and seen as a hyper-reflective surface. In 7 eyes the posterior surface of the silicone appeared to bridge the macular hole or foveal depression continuous with its contact along retinal tissue at either edge, leaving a pre-foveal or pre-RPE fluid pocket underneath the oil tamponade (Fig 1 a-d). Of note, in some scans only the center reflex of the posterior concavity of the oil could be seen as a hyper-reflective spot “floating” internal to the macular hole, and in other cases a large portion of oil meniscus along the retinal surface was visible (Fig 1).

In 3 eyes (30% of eyes studied), the silicone oil appeared to “fill” the pre-foveal or macular hole space completely. In these eyes, the silicone was seen in contact with the retinal surface throughout the foveal depression or, in one particularly large macular hole measured at over 1000um in diameter by SD-OCT, the oil filled in the macular hole and could be seen touching the RPE (Fig 1 e-h).

Next we evaluated how the oil-retinal interface changed with respect to patient positioning. The Heidelberg Spectralis was used, and SD-OCT images taken in upright and prone position. Of the four patients evaluated this way, in three cases the scans showed the same relationship of oil and retina irrespective of positioning (Fig 1, e-h). In the fourth patient, a pre-foveal fluid pocket was seen on the upright images, but a complete fill evident with face-down posture (Fig 2). In this same patient, images were taken in the lateral and supine positions with the patient lying on a stretcher. Lateral scans showed a pre-foveal space oil position equivalent to upright imaging. However, supine positioning pooled aqueous fluid to the most dependent position, the macular region, creating a large fluid collection over the macula beneath the silicone bubble floating above (Fig 2).

Finally, a single patient was imaged successfully with C3F8 gas tamponade in both upright and face down position. Images were far clearer in the face-down posture, while aqueous fluid was pooled on to the posterior surface of the lens, but upright and face-down positions revealed equivalent morphology, with the gas surface bridging the macular hole and creating a pre-foveal space (Fig 3a,b). This patient later underwent re-operation with silicone oil tamponade for a recurrent macular hole in the same eye. SD-OCT images using the Heidelberg Spectralis after this surgery reveal a complete oil fill over a closed macular hole in both face-forward and face-down position (Fig 3c,d). Additionally, the same patient underwent SD-OCT scans with the OPKO-OTI machine in the seated, face-forward position. These images, matching the Spectralis scans, revealed a complete oil fill without a pre-foveal fluid pocket (Fig 3e,f). Images of the same eye are markedly cleared through silicone oil (3c-f) than C3F8 gas (3a,b).

Discussion

We used SD-OCT to study the dynamics of the silicone oil-macular hole interface during the post-operative period. We did not attempt to evaluate the surgical success of silicone oil tamponade, or compare it to outcomes with intra-ocular gas, but instead focused on the oil-retina apposition after silicone oil use. Our images show that when patients are upright, silicone oil “waterproofs” macular holes by either bridging across them or, in a new observation, by completely filling the pre-foveal space. In the majority (3/4 eyes) of cases studied, the oil-retina relationship did not vary between upright and prone position, suggesting that with silicone oil use face-down and upright positioning are equivalent.

The need for face-down positioning after macular hole surgery remains a topic of debate,¹³ and several reports provide good evidence that with intra-ocular gas tamponade successful macular hole surgery may not require positioning as long as the initial gas bubble is large enough to isolate the macular hole.^{14,15} Silicone oil tamponade has traditionally been reported as freeing patients from positioning, but even successful published series of macular hole closure with silicone oil instructed patients to sleep face-down the first night after surgery and restricted only supine position thereafter.⁵ Is it believed that surgery without positioning works because the tamponade needs only to isolate, or “waterproof,” the macular hole from fluid in the vitreous cavity.¹³ If this is the case, our data about the retina-oil approximation suggests that silicone oil effectively waterproofs macular holes by filling or bridging across them regardless of face-down or upright position. However, some proponents of more extended posturing have suggested that the tamponade must provide a mechanical “flotation force” at its apex against the macular hole while patients are face-down,³ and if this is the case then prone posture may remain advantageous despite our images that the retinal-oil approximation remains intact while upright.

In a single patient, silicone oil appeared to fill the underlying macular hole and directly contact the RPE (Patient 8, Fig 1g-h). While no sub-retinal fluid remained at the macular hole edges, previously referred to as a “flat and open configuration,”¹⁶ in this case the silicone oil itself may hinder physical connection of the retinal edges, essentially “sealing” macular holes into the flat and open configuration. Additionally, in vitro evidence suggests that silicone oil may have direct effects on cultured RPE cells¹⁷ and our images of oil-RPE touch raise concern that the sub-foveal RPE cells could be injured by the tamponade. This is far less likely with gas tamponade, as the higher surface tension of intra-ocular gases compared to silicone oil makes deformation of the bubble into the macular hole and against the RPE less likely.

The physical properties of silicone oil may help explain its behavior over the retina. While higher centistoke silicone oil has a greater purity, leading to more resistance to emulsification, high and low centistoke oils have a similar surface tension.^{18,19} The oil surface tension is lower than intraocular gas tamponades, and might explain why silicone oil deforms at the edge of a bubble to fill the prefoveal, or macular hole, space. In a single patient we successfully imaged the edge of a gas bubble bridging a macular hole (Fig 3 a,b), but we were not able to consistently image gas-filled eyes. Successful visualization of the gas bubble and underlying retina was possible in only 1 of 4 patients, and better images were obtained in the face down position than upright. Similarly, a prior report monitoring macular hole closure in gas filled eyes used face-down time domain OCT images.²⁰

Complete filling of the vitreous cavity is an important variable in macular hole surgery, and more successful efforts to use oil tamponade were meticulous about completeness of fill.^{5,6} However, our evidence that supine positioning floats the silicone oil tamponade off of the retinal surface (Fig 2d) reveals that there is enough residual fluid in the vitreous cavity even

with a good oil fill to cause this separation, and that supine position should be avoided post-operatively.

A recent study reports good anatomical and visual outcomes after macular hole surgery with the heavy silicone oil (HSO) Densiron-68.²¹ With specific gravities of greater than 1.0, HSOs “sink” in the vitreous cavity, and in the above study patients were positioned supine for the first day after surgery. HSOs are unavailable to us for surgical use and therefore not included in this SD-OCT positioning study, however, the interfacial tension of HSOs is slightly lower than that of traditional silicone oils.^{22,23} This suggests that HSOs are slightly more deformable, and in turn may be more likely to conform with the retinal contour, or fill a macular hole even touching the RPE (as in Fig 1g,h), rather than take a bridging conformation.

It is worth noting that this study uses two different SD-OCT machines (Table 1). The Heidelberg Spectralis was used for all face-down, sideways, and supine imaging because the camera head can be easily dismounted to accommodate patient positioning, and became our SD-OCT of choice for post-operative macular hole patients. However, one patient who was able to position and displayed complete oil fill of the foveal depression (patient 9), was imaged on both machines. As expected, this inter-SD-OCT comparison revealed matching silicone oil morphologies (Figure 3 C-F), suggesting that the two machines are consistent in how they capture the oil-retinal interface.

In conclusion, silicone oil tamponade either bridges across macular holes, or in a novel finding, conforms with the retinal contour to fill the prefoveal space or macular hole itself. Generally, the oil position is stable between face-forward and prone SD-OCT images, suggesting that either of these patient positions allows waterproofing of the underlying macular hole. Finally, our images confirm that supine positioning should be avoided post-operatively as it leads to loss of oil-retinal tamponade.

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References

1. Kelly NE, Wendel RT. Vitreous surgery for idiopathic macular holes. Results of a pilot study Arch Ophthalmol 1991;109:654–9.
2. Margherio AR. Macular hole surgery in 2000. Curr Opin Ophthalmol 2000;11:186–90. [PubMed: 10977225]
3. Thompson JT, Smiddy WE, Glaser BM, et al. Intraocular tamponade duration and success of macular hole surgery. Retina 1996;16:373–82. [PubMed: 8912962]
4. Freeman WR, Azen SP, Kim JW, et al. Vitrectomy for the treatment of full-thickness stage 3 or 4 macular holes. Results of a multicentered randomized clinical trial. The Vitrectomy for Treatment of Macular Hole Study Group. Arch Ophthalmol 1997;115:11–21. [PubMed: 9006420]
5. Goldbaum MH, McCuen BW, Hanneken AM, et al. Silicone oil tamponade to seal macular holes without position restrictions. Ophthalmology 1998;105:2140–7. [PubMed: 9818619]
6. Pertile G, Claes C. Silicone oil vs. gas for the treatment of full-thickness macular hole. Bull Soc Belge Ophthalmol 1999;274:31–6. [PubMed: 10670160]
7. Lai JC, Stinnett SS, McCuen BW. Comparison of silicone oil versus gas tamponade in the treatment of idiopathic full-thickness macular hole. Ophthalmology 2003;110:1170–4. [PubMed: 12799243]
8. Kumar V, Banerjee S, Loo AV, et al. Macular hole surgery with silicone oil. Eye 2002;16:121–125. [PubMed: 11988809]
9. Tornambe P. Discussion of Silicone oil tamponade to seal macular holes without position restrictions. Ophthalmology 1998;105:2147–8.

10. Jumper JM, Gallemore RP, McCuen BW 2nd, Toth CA. Features of macular hole closure in the early postoperative period using optical coherence tomography. *Retina* 2000;20:232–7. [PubMed: 10872926]
11. Satchi K, Patel CK. Posterior chamber compartments demonstrated by optical coherence tomography, in silicone-filled eyes, following macular hole surgery. *Clin Experiment Ophthalmol* 2005;33:619–22. [PubMed: 16402955]
12. Kokame GT, Yamamoto I. Silicone oil versus gas tamponade. *Ophthalmology* 2004;111:851–2. [PubMed: 15051230]
13. Gupta D. Face-down posturing after macular hole surgery: a review. *Retina* 2009;29:430–43. [PubMed: 19359978]
14. Tornambe PE, Poliner LS, Grote K. Macular hole surgery without face-down positioning. A pilot study *Retina* 1997;17:179–85.
15. Dhawahir-Scala FE, Maino A, Saha K, Mokashi AA, McLauchlan R, Charles S. To posture or not to posture after macular hole surgery. *Retina* 2008;28:60–5. [PubMed: 18185139]
16. Tornambe PE, Poliner LS, Cohen RG. Definition of macular hole surgery end points: elevated/open, flat/open, flat/closed. *Retina* 1998;18:286–7. [PubMed: 9654428]
17. Friberg TR, Verstraeten TC, Wilcox DK. Effects of emulsification, purity, and fluorination of silicone oil on human retinal pigment epithelial cells. *Invest Ophthalmol Vis Sci* 1991;32:2030–4. [PubMed: 1676022]
18. Nakamura K, Refojo MF, Crabtree DV. Factors contributing to the emulsification of intraocular silicone and fluorosilicone oils. *Invest Ophthalmol Vis Sci* 1990;31:647–56. [PubMed: 1692310]
19. Heidenkummer HP, Kampik A, Thierfelder S. Experimental evaluation of in vitro stability of purified polydimethylsiloxanes (silicone oil) in viscosity ranges from 1000 to 5000 centistokes. *Retina* 1992;12:S28–32. [PubMed: 1455079]
20. Eckardt C, Eckert T, Eckardt U, Porkert U, Gesser C. Macular hole surgery with air tamponade and optical coherence tomography-based duration of face-down positioning. *Retina* 2008;28:1087–96. [PubMed: 18779715]
21. Schurmans A, Van Calster J, Stalmans P. Macular hole surgery with inner limiting membrane peeling, endodrainage, and heavy silicone oil tamponade. *American Journal of Ophthalmol* 2009;147:495–500.
22. Heimann H, Stappler T, Wong D. Heavy tamponade 1: a review of indications, use, and complications. *Eye* 2008;22:1342–59. [PubMed: 18344952]
23. Nakamura K, Refojo MF, Crabtree DV. Factors contributing to the emulsification of intraocular silicone and fluorosilicone oils. *Invest Ophthalmol Vis Sci* 1990;31:647–56. [PubMed: 1692310]

Figure 1.

Silicone oil-retinal approximations in four different seated, upright patients showing a prefoveal fluid pocket (A, B, C, D). Also shown are examples of tamponade in which the silicone oil dips into the foveal depression (E) and retains that conformation with face-down positioning (F), and of the silicone oil filling in a flat and open macular hole to touch the retinal pigment epithelium in both upright (G) and face-down positioning (H).

Figure 2.

SD-OCT images of Patient 6 in four different positions including seated and faced-forward with a pre-foveal fluid pocket (A), face-down with the silicone oil shifted and the oil apex now touching the fovea (B), lying sideways with a pre-foveal fluid pocket (C), and supine with a large fluid collection separating the retina from silicone oil floating above (D).

Figure 3.

SD-OCT images of Patient 9 including after her first macular hole surgery with C3F8 gas in the seated face-forward position (A) and face-down position (B) showing equivalent gas tamponade unchanged with positioning, and after repeat macular hole surgery with silicone oil in the seated face-forward position (C) and face-down position (D) showing a complete oil fill into the foveal depression that is unchanged with positioning. Images in panels A-D are taken with the Heidelberg Spectralis OCT, and the final images (E,F) are taken with the OPKO-OTI OCT and show the same patient in the seated face-forward position with a complete oil fill matching the findings in panels C and D.

Table 1

Patient Characteristics and Silicone Oil Positions

Patient	Age	Eye	Upright-Seated Configuration	Positional Change	Oil Type (cs)	Machine
1	77	—	Prefoveal fluid pocket	N/A	5,000	OPKO
2	74	—	Prefoveal fluid pocket	N/A	5,000	OPKO
3	76	—	Prefoveal fluid pocket	N/A	5,000	OPKO
4	77	—	Prefoveal fluid pocket	N/A	5,000	OPKO
5	58	—	Prefoveal fluid pocket	N/A	5,000	OPKO
6	59	OD	Complete fill	No	1,000	HRA
		OS	Prefoveal fluid pocket	Yes	1,000	HRA
7	73	—	Complete fill	Patient unable	5,000	HRA
8	67	—	Complete fill with RPE touch	No	5,000	HRA
9	61	OD C ₃ F ₈	Prefoveal fluid pocket	No	5,000	HRA
		OD oil	Complete fill	No	5,000	HRA
		OD oil	Complete fill	N/A	5,000	OPKO

Patient 7 was unable to flex forward for prone imaging.

cs, centistoke; N/A, not possible to do positional imaging with the OPKO machine; OD, right eye; OS, left eye.