Comparison of Silicone Oil Versus Gas Tamponade in the Treatment of Idiopathic Full-thickness Macular Hole

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Purpose: To compare anatomic and functional outcomes of macular hole surgery with either silicone oil or C_3F_8 gas tamponade.

Design: Retrospective comparative interventional study.

Participants: Fifty-four eyes of 51 patients underwent pars plana vitrectomy for macular holes. Thirty-one eyes were treated with silicone oil tamponade, and 23 eyes were treated with C_3F_8 tamponade.

Methods: Demographics, preoperative and postoperative characteristics, and complications were analyzed.

Main Outcome Measures: Preoperative and postoperative visual acuity, initial hole closure, number of persistent or recurrent holes, number of reoperations, and final hole closure.

Results: The silicone oil and gas tamponade groups were demographically similar. The rate of hole closure after one operation with oil tamponade was significantly lower than that with gas tamponade (65% vs. 91%; $P = 0.022$). The percentage of patients undergoing a second operation was significantly higher in the oil group (35% vs. 4%; $P = 0.006$). However, with reoperations, the final rate of hole closure was similar between the oil and gas groups (90% vs. 96%; $P = 0.628$). The final median visual acuity for the gas group was significantly better than for the oil group (20/50 vs. 20/70; $P = 0.047$).

Conclusions: C_3F_8 gas proved to be a more effective tamponade than silicone oil with respect to achieving initial closure of macular holes. Eyes receiving an oil tamponade required significantly more reoperations to achieve a similar rate of hole closure compared with eyes undergoing a gas tamponade. Final visual acuity was better for gas-operated eyes than for silicone-operated eyes. *Ophthalmology 2003;110:1170–1174 © 2003 by the American Academy of Ophthalmology.*

Since the original report by Kelly and Wendel,[1] multiple studies have demonstrated that pars plana vitrectomy with air–fluid exchange can close macular holes with subsequent improvement in visual acuity.[2–5] Most authors have suggested that the willingness and ability of patients to maintain a face-down position after surgery when a gas tamponade is used is an important part of achieving success in macular hole surgery.[6] However, some patients are unable to appropriately position themselves after surgery because of medical, physical, or social conditions. Another disadvantage of gas tamponade is that patients are also restricted from flying or traveling to high altitudes when the vitreous cavity is filled with gas, because of the possibility of rapid gas expansion and resultant closure of the retinal or choroidal circulation.

Silicone oil (SO) tamponade without postoperative positioning requirements has been demonstrated to be a safe alternative to gas in the treatment of idiopathic macular holes.[7,8] In addition, patients who receive silicone oil as an intraocular tamponade are not restricted from flying during the recovery period, and they maintain useful vision in the eye during the tamponade period. Patients with SO tamponade, however, must undergo a second operation to remove the oil, and can sometimes detect residual oil droplets left behind in the vitreous cavity.

The reported rate of surgical success in macular hole patients treated with an SO tamponade has varied.[7–9] Because of the uncertainty of the relative effectiveness of SO as a tamponade, we sought to determine whether the use of SO vs. C_3F_8 gas tamponade in idiopathic macular hole surgery affects anatomic and functional outcomes.

Methods

We performed a retrospective comparative interventional study of 54 consecutive eyes in 51 patients with macular holes. All participants in the study underwent pars plana vitrectomy by one author (BWM) during the period of February 1998 to August 2001. This

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time interval was selected because of the uniformity of the surgical technique that was used during this period.

Inclusion criteria included the presence of either an idiopathic macular hole (stages 2–4) or a recurrent macular hole. Stage 2 macular holes were <400 μm in diameter, stage 3 holes were ≥400 μm, and stage 4 holes coexisted with a complete posterior vitreous detachment.[10] Eyes with a history of macular hole surgery and subsequent early or late hole reopening were classified as having recurrent holes.

All participants were informed of the relative advantages and disadvantages of both C_3F_8 gas and SO for use as a temporary intraocular tamponade. Selection of tamponade to be used in this series was determined by the preference of the patient.

All participants underwent a complete ophthalmic examination, including best-corrected Early Treatment Diabetic Retinopathy Study visual acuity testing, applanation tonometry, slit-lamp examination, and dilated fundoscopic examination. All acuities were converted to the logarithm of the minimum angle of resolution (logMAR) for statistical analysis. The final best-corrected visual acuity, initial hole closure, number of persistent or recurrent holes, number of reoperations, and final hole closure were recorded.

Surgery was performed with monitored anesthesia care and a retrobulbar block. The crystalline lens was not removed during the initial surgery or during the removal of SO. A soft-tip aspirating cannula and fiberoptic pick were used to create a posterior vitreous separation at the optic disc in stage 2 and 3 macular holes. The posterior cortical vitreous was then peeled across the macula and into the periphery 360°. A complete vitrectomy was performed as far peripherally as safely possible. The retinal periphery was inspected for retinal breaks, and any breaks found were treated with either cryopexy or laser. A fluid–air exchange procedure was then performed with humidified air. In most eyes with stage 3 and 4 holes and in all recurrent holes, an attempt was made to peel the internal limiting membrane (ILM). Indocyanine green (ICG) dye (Akorn Inc., Buffalo Grove, Il) was used in certain cases after fluid–air exchange to facilitate identification of the ILM. In those cases, 25 mg of sterile ICG powder was initially reconstituted in 0.5 ml of provided aqueous solvent and then subsequently diluted in 4.5 ml of balanced salt solution for a final concentration of 0.5% ICG. Two drops of the ICG dye were then placed over the macular area for 1 minute. The infusion was then restarted and the air removed. A Tano soft-tipped diamond-dusted scraper (Synergetics, St. Louis, MO) was used to elevate the ILM, and the ILM was peeled away from the macular hole for 360°. An ILM forceps was used to complete a maculorrhexis. The fluid–air exchange was then repeated with drainage of preretinal fluid over the optic disc. The air was then exchanged for sterile 20% C_3F_8 gas. For patients who chose SO tamponade, a direct fluid–SO exchange was performed by using SO of either 5000 (26 eyes) or 1000 centistoke (5 eyes) viscosity.

Participants who underwent gas tamponade were instructed to maintain strict prone positioning for 2 weeks. Participants who underwent SO tamponade were encouraged to sleep face-down on the night of surgery, after which they were instructed to avoid supine positioning but were otherwise able to assume any position of comfort.

Hole closure was assessed by using both clinical examination and optical coherence tomography. A hole was determined to be closed if the edges were not visualized or if the edges were flat against the retinal pigment epithelium with no cuff of subretinal fluid. The lens clarity was qualitatively graded with the slit lamp from 0 (clear) to 4 (20/200 or worse view of the retina). Approximately 2 months after the initial surgery, the SO was removed through passive efflux. Residual droplets of SO were removed through a short, thin-walled 19-gauge cannula.

Table 1. Patient Demographics and Eye Characteristics

Variable	Oil (n = 31)	Gas (n = 23)	*P* Value
Sex			0.626*
Male, n (%)	10 (30%)	5 (24%)	
Female, n (%)	21 (70%)	16 (76%)	
Age, yrs, mean (standard deviation)	70.4 (5.6)	68.3 (4.4)	0.148†
Duration of symptoms, n (%)			1.000‡
<1 y	30 (97%)	22 (96%)	
≥1 y	1 (3%)	1 (4%)	
Preoperative phakic status, n (%)			0.957*
Phakic	20 (65%)	15 (65%)	
Pseudophakic	11(35%)	8 (35%)	
Stage, n (%)			0.444‡
2	6 (19%)	8 (35%)	
3	16 (52%)	7 (30%)	
4	4 (13%)	3 (13%)	
Recurrent	5 (16%)	5 (22%)	
Preoperative visual acuity			
Range	20/40 to 20/1000	20/40 to HM	
20/40 < *x* ≤ 20/100	19 (61%)	15 (65%)	0.487‡
20/100 < *x* ≤ 20/200	8 (26%)	3 (13%)	
20/200 < *x*	4 (13%)	5 (22%)	
Median	20/100	20/80	0.573§

*Chi-square test.
†*t* test.
‡Fisher exact test.
§Wilcoxon's ranked sum test.
HM = hand motion.

Initially, descriptive statistics for demographic and background variables and for outcome measures were computed separately for the oil and gas groups. The statistical significance between the groups for categorical variables was assessed by using either chi-square or Fisher exact tests. For continuous variables, either a *t* test or Wilcoxon's ranked sum test was used.

Several additional comparisons of outcomes between categories of selected variables were of interest. The outcomes included median final logMAR visual acuity, final hole closure, number of reoperations at Duke, hole reopenings, and recurrent macular holes. Variables for which these outcomes were compared were tamponade (oil vs. gas), viscosity in the oil group (1000 vs. 5000), preoperative phakic status, stage (2, 3, 4, or recurrent), attempted ILM peeling with and without ICG, and success of membrane peeling. For categorical outcomes, comparisons among categories were made with the chi-square or Fisher exact test. For continuous outcomes, comparisons among categories were made with Wilcoxon's ranked sum test or the Kruskal–Wallis test.

Results

Patient Demographics and Eye Characteristics

A total of 54 eyes of 51 patients were included in this study: 31 eyes in the SO group and 23 eyes in the gas group. There were no statistical differences between the groups in terms of gender, age, duration of macular hole, preoperative phakic status, or stage of hole (Table 1). In the oil group, 19% (6/31) of holes were stage 2, 65% (20/31) were stage 3 or 4, and 16% (5/31) were recurrent macular holes. In the gas group, 35% (8/23) of holes were stage 2, 43% (10/23) were stage 3 or 4, and 22% (5/23) were recurrent

Table 2. Surgical Outcomes

Variable	Oil (n = 31)	Gas (n = 23)	P value
Attempted ILM peeling, n (%)	28 (90%)	19 (83%)	0.443*
ICG-assisted ILM peeling, n (%)	7 (23%)	6 (26%)	0.766†
Successful membrane peeling, n (%)	16 (57%)	13 (68%)	0.435†
Initial hole closure rate, n (%)	20 (65%)	21 (91%)	0.022*
Persistent macular hole, n (%)	6 (20%)	1 (4%)	0.123*
Recurrent macular hole, n (%)	5 (16%)	1 (4%)	0.224*
Final hole closure rate, n (%)	28 (90%)	22 (96%)	0.628*
No. of reoperations, n (%)	11 (35%)	1 (4%)	0.006†
Postoperative phakic status at last follow-up			
Phakic	5 (16%)	12 (52%)	
Pseudophakic	26 (84%)	11 (48%)	
Median follow-up (mos)	9.0	4.0	0.002‡

*Fisher exact test.
†Chi-square test.
‡Wilcoxon's ranked sum test.
ILM = internal limiting membrane; ICG = indocyanine green.

macular holes. No difference in median preoperative visual acuity existed between the gas- and oil-treated eyes, and approximately the same percentage of eyes in both groups presented with an initial visual acuity of at least 20/100 (Table 1).

Surgical Outcomes

No differences in frequency of attempted ILM peeling, use of ICG, or success of ILM peeling existed between the two groups (Table 2). All eyes in both the oil and gas groups had a >80% tamponade fill on postoperative day 1. The median follow-up times for the gas and oil groups were significantly different (4.0 vs. 9.0 months; $P = 0.002$).

Closure Rates

Oil. The macular hole was sealed in 65% (20/31) of eyes after a single silicone fill (Table 2). Six eyes (20%) had a visibly persistent hole after a single surgery. Two (33%) of these 6 eyes had had previous macular hole surgery elsewhere before their operation at Duke. Five eyes (16%) developed a recurrent macular hole after SO removal. The median time to development of the recurrent hole was 12 weeks (range, 3–20 weeks). Two (40%) of these eyes had had previous macular hole surgery elsewhere before their operation at Duke. Four of these recurrences occurred in phakic eyes, and one occurred after cataract surgery. All 11 eyes (6 persistent and 5 recurrent holes) underwent a second operation; of these, 8 achieved hole closure. Including reoperations, 90% (28/31) of eyes ultimately achieved macular hole closure in the oil group.

Gas. The macular hole was sealed in 91% (21/23) of eyes after one operation with a gas tamponade (Table 2). One eye had a persistent hole, and another developed a late recurrent macular hole after cataract surgery. The participant with the persistent hole was pseudophakic and had a stage 3 hole before surgery. This patient opted against additional surgery. The patient with late reopening of the macular hole underwent a reoperation with gas tamponade, with successful hole closure. Including reoperations, the percentage of eyes that achieved final macular hole closure for the gas group was 96% (22/23).

Comparison of Oil and Gas. The rate of hole closure after a single operation with oil tamponade was significantly lower than that with gas tamponade (65% vs. 91%; $P = 0.022$). The rate of reoperation in the oil group was significantly higher than in the gas group (35% vs. 4%; $P = 0.006$). However, with reoperations, the final rate of macular hole closure was not statistically different between the oil and gas groups (91% vs. 96%; $P = 0.628$). Eyes with recurrent macular holes on initial presentation were more likely to develop a persistent or recurrent macular hole after surgery if they received SO as a tamponade (4/5) compared with gas (0/5; 80% vs. 0%; $P = 0.047$). Preoperative phakic status, use of ICG, success of ILM peeling, or subsequent cataract surgery did not affect final closure rate.

Final Visual Acuity

A 0.1 logMAR score change is equivalent to a single-line change on the Early Treatment Diabetic Retinopathy Study visual acuity chart. The median visual acuity increased by 0.16 logMAR units (1.6) lines in the oil tamponade group and by 0.2 logMAR units (2 lines) in the gas tamponade group (Table 3). The final median visual acuity for the gas tamponade group (20/50; range, 20/20 to 20/160) was better than for the oil group (20/70; range, 20/25 to 20/632; $P = 0.047$). Average lines of improvement in visual acuity by grade of macular hole are summarized in Table 3. The final median visual acuity in the gas group remained significantly better than the oil group (20/45 vs. 20/66; $P = 0.02$), even when eyes were excluded that initially presented with recurrent macular holes.

Complications

No complications were noted during ILM peeling in either group. Peripheral tears noted during surgery (gas, 4 eyes; oil, 3 eyes) were treated successfully at the time of the operation with either

Table 3. Postoperative Visual Outcomes

Variable	Oil		Gas	
	Median Final Visual Acuity	*Lines of Improvement*	*Median Final Visual Acuity*	*Lines of Improvement*
All stages*	20/70	1.6	20/50	2.0
Stage 2†	20/45	2.1	20/34	2.2
Stage 3	20/70	2	20/60	2.4
Stage 4	20/53	2.5	20/30	4.2
Recurrent holes	20/200	3	20/64	1

*The median final visual acuity for the gas-treated eyes was significantly better than for oil-treated eyes ($P = 0.047$).
†The lines of improvement in visual acuity were not statistically different between the individual stages of holes for both oil ($P = 0.707$) and gas ($P = 0.852$).

cryopexy or laser treatment. No retinal detachments developed in any of the eyes. The oil group experienced a median worsening of 2 grades in their lens clarity, whereas the gas group experienced a median worsening of a single. A significantly greater proportion of eyes in the oil vs. the gas group subsequently underwent cataract surgery (48% vs. 13%; $P = 0.006$). The mean interval between the initial macular hole surgery and subsequent cataract surgery was 40 weeks (n = 15; range, 24–72 weeks) for the oil group and 43 weeks (n = 3; range, 24–72 weeks) for the gas group. One participant was brought back to the operating room for removal of a symptomatic residual droplet of SO after the initial oil removal. No other complications were associated with oil removal.

Discussion

Successful macular hole closure is probably influenced by multiple factors. Proposed variables include the size and chronicity of the macular hole,[11,12] use of biologic adjuvants,[13–15] peeling of ILM,[16,17] and duration of postoperative positioning.[6,18] Whether the choice of intraocular gas or SO as a surgical tamponade in macular hole surgery also affects surgical success is unclear. Using SO without postoperative positioning, Goldbaum et al[7] reported an 80% closure rate for stage 2 to 4 holes and an average improvement of 2.6 lines in visual acuity. In a comparison of SO vs. SF_6 gas tamponade, Pertile and Claes[8] found closure rates to be >94% in both groups and found a slightly better visual outcome in the oil group. In contrast, Voo et al[9] achieved only a 50% initial closure rate when using oil as a tamponade and raised the possibility that oil is less effective than gas for the closure of macular holes.

Our results suggest that anatomic and visual outcomes are better in eyes undergoing gas compared with SO tamponade. Although the final rate of hole closure was similar between the 2 groups, the gas group had a much higher closure rate after a single operation and, consequently, required significantly fewer reoperations. Furthermore, all eyes in the gas group that had undergone a previously failed macular hole repair operation were successfully repaired with an additional operation. In contrast, 80% (4/5) of eyes in the oil group that initially presented with a recurrent macular hole developed either a persistent or recurrent hole after reoperation. Final visual acuities in eyes that received a gas tamponade were also significantly better than in those treated with oil.

The surgical outcomes in our gas group were similar to recently reported results in the literature. Several studies, including ours, have found initial closure rates to be >90% when extended gas tamponade is used with postoperative positioning.[5,16,17,19] However, it is difficult to compare the results of our oil group with results of previously published reports that used SO, because of differences in patient selection and surgical techniques among the studies. For example, in contrast to this study's technique, Goldbaum et al[7] did not attempt ILM peeling in most of their eyes. Conversely, whereas we did not use surgical adjuvants, Voo et al[9] used an adjunctive agent in all but one of their eyes. It is unclear whether these variations in surgical technique offer any surgical or functional benefit.[13,16,17] However, comparisons between the results of the various studies should be performed very cautiously.

It is unclear why anatomic and visual outcomes were worse in the SO group. The shorter follow-up period in the gas group may have resulted in an underreporting of late hole reopenings when compared with the oil group. Underfill of oil (<80%) has also been proposed as a major determinant in surgical failure.[7] However, this hypothesis could not be tested in our study. The poorer outcomes in our oil group occurred despite good oil fills (>80%) in all study eyes. Another theory to explain the better outcomes in the gas group is that the gas-treated eyes may have developed a glial response over the macular hole that enhanced the adhesion.[20,21] It is unclear whether a similar response occurs in oil-sealed eyes, and further studies are needed to determine this. Direct macular toxicity related to SO adversely affecting visual acuity is also possible, although there has been little evidence of this.

An additional hypothesis that accounts for the superior ability of a gas tamponade to achieve sustained macular hole closure compared with SO involves the greater buoyancy of gas relative to SO. Because gas has >30 × the flotation force of SO, it is much more effective in mechanically apposing the dehisced hole edges and pushing the retina against the pigment epithelium. This additional benefit of gas may have added to the beneficial effect of the sequestration of the macular hole from the vitreous fluid currents achieved by both tamponades.

Our study has the limitations of an uncontrolled retrospective study. An unforeseen selection bias may have existed for participants who entered the silicone group because of an inability to position. However, many of the participants in the oil group were actually good candidates for either gas or oil tamponade. We suspect that the disproportionately higher rate of participants who chose oil tamponade resulted from patients being specifically referred to Duke because of the known experience of the surgeon (BWM) with oil in the treatment of macular holes. However, because the preoperative patient demographics and eye characteristics were similar between the oil and gas groups, one would expect the effect of any selection bias to be minimal.

It is also unlikely that the slightly higher number of stage 2 holes in the gas-treated eyes skewed final visual outcomes in favor of that group. First, the differences between the gas and oil groups with respect to the distribution of macular hole stages were not statistically significant. Second, median preoperative visual acuities were similar. Third, subgroup analysis of preoperative visual acuities revealed that the percentages of participants with a preoperative visual acuity between 20/40 and 20/100 were similar between the gas and oil groups. In fact, the actual visual acuity differences between the groups may have been underestimated by the shorter follow-up time in the gas-treated eyes. Longer follow-up was available for oil-treated participants not only because they had to return for their oil removal, but also because they were more likely to undergo cataract surgery. At their last follow-up, significantly more participants treated with oil had undergone cataract surgery as compared with participants treated with gas. As a result, an even greater visual acuity improvement in the gas group may have been found had a similar number of patients in this group undergone cataract surgery after the repair of their macular hole.

SO remains a viable alternative for patients who are poor candidates for gas tamponade. However, the potential benefits of SO must be carefully weighed against the need for a second operation for oil removal and against the significantly poorer anatomic and visual outcomes in oil-treated eyes. Patients who can appropriately position themselves after surgery and those who present with a recurrent macular hole should be advised to undergo macular hole surgery with gas tamponade.

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