THE IN VITRO ANTIMICROBIAL ACTIVITY OF SILICONE OILS USED IN OPHTHALMIC SURGERY

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\begin{enumerate}
\item Background. The aim of the study was in vitro assessment and comparison of the antimicrobial activity of three types of silicone oils used in ophthalmic surgery.
\item Methods. The silicone oils (Arciolane 1300 centistokes, Arciolane 5500 centistokes and Oxane Hd, heavy silicone oil) were inoculated with microbes common in endophthalmitis and their growth was observed continuously. Control tests of microbial growth were performed on silicone oil-free media, i.e. saline and standard enrichment media. In both tested oils and control media, the microbes were cultured aerobically for 21 days, bacteria at 37 °C and yeasts and fungi at 30 °C. Prior to and during incubation at given intervals (days 0, 2, 4, 7, 9, 11, 14, 16, 18 and 21), 10 μl samples were taken from all test tubes. These were diluted in saline in a series of test tubes, with the minimum concentration reaching \(10^8\). From each dilution, 25 μl were inoculated onto agar media. After 24 h of aerobic incubation at 37 °C (bacteria) and 48 h at 30 °C (yeasts and fungi), the grown colonies were counted and the numbers of colony-forming units in 1 ml (CFU/ml) were determined.
\item Results. In vitro, the highest antimicrobial effect was observed for the Oxane Hd silicone oil.
\item Conclusions. If endophthalmitis is treated by pars plana vitrectomy, the application of Oxane Hd silicone oil into the vitreous cavity at the end of surgery may contribute to the elimination of microorganisms from the intraocular space but clinical trials are needed to assess its safety.
\end{enumerate}

INTRODUCTION

Silicone oil is used in vitreoretinal surgery for internal tamponade. It is used especially in complex cases of rhegmatogenous retinal detachment if the condition is complicated by proliferative vitreoretinopathy and giant retinal tears\textsuperscript{1-3}. In cases where the proliferative vitreoretinopathy and retinal breaks are found in the lower periphery of the retina, the use of heavy silicone oil is also considered\textsuperscript{4,5}.

It may be indicated too, in patients with proliferative diabetic retinopathy for conditions connected to repeated intravitreal hemorrhage, tractional retinal detachment, traction-rhegmatogenous retinal detachment and tractional retinal detachment with neovascular glaucoma\textsuperscript{6-7}. The literature also mentions the antimicrobial activity of silicone oil which may improve the surgical treatment of endophthalmitis\textsuperscript{8-10}. At present, a large number of silicone oil variants which differ in viscosity and specific gravity, are available for use in vitreoretinal surgery. These differences may affect their antimicrobial activity and thus the treatment of endophthalmitis which is a very serious condition caused by common pathogens. This study aimed at in vitro assessment and comparison of the antimicrobial effects of silicone oils with viscosities of 1,300 centistokes (cSt) and 5,500 cSt and heavy silicone oil.

MATERIAL AND METHODS

The antimicrobial activity was tested for the following types of silicone oils: Arciolane 1300 cSt (Arcadoph ta, France), Arciolane 5500 cSt (Arcadphta, France) and Oxane\textsuperscript{a} Hd (Bausch & Lomb Inc., Ireland). The oil was inoculated with microbes etiologically most common in endophthalmitis, i.e. \textit{Staphylococcus aureus}, \textit{Staphylococcus epidermidis}, \textit{Enterococcus faecalis}, \textit{Bacillus sp.}, \textit{Pseudomonas aeruginosa}, \textit{Candida albicans} and \textit{Aspergillus fumigatus}. The growth capability of the inoculated agents was then observed continuously. The strains were obtained during routine microbiological analyses from patients at the University Hospital Olomouc. Control tests for microbial growth were performed on silicone oil-free media, i.e. saline and standard enrichment media BHI (HiMedia, India) in the case of bacteria, or GPB (Trios, Czech Republic) in the case of yeasts and fungi. 0.1 ml of 1 McFarland standard microbial suspension was pipetted into 0.9 ml of silicone oil, saline and enrichment medium. In both the tested oils and control media, the microbes were cultured aerobically for 21 days, bacteria at 37 °C and yeasts and fungi at 30 °C. After careful mixing in a vortex, 10 μl samples were taken from all test tubes (with both inoculated oils and control media).
Fig. 1. The effects of silicone oils, saline and BHI on the survival of *Staphylococcus aureus*.

Fig. 2. The effects of silicone oils, saline and BHI on the survival of *Staphylococcus epidermidis*.

Fig. 3. The effects of silicone oils, saline and BHI on the survival of *Enterococcus faecalis*. 
Fig. 4. The effects of silicone oils, saline and BHI on the survival of *Bacillus* sp.

![Graph showing antimicrobial activity of silicone oils on Bacillus sp.]

**Bacillus sp.**

- **log CFU/ml**
- **time/days**
- **Arciolane 1300**
- **Arciolane 5500**
- **Oxane Hd**
- **Saline**
- **BHI**

Fig. 5. The effects of silicone oils, saline and BHI on the survival of *Pseudomonas aeruginosa*.

![Graph showing antimicrobial activity of silicone oils on Pseudomonas aeruginosa]

**Pseudomonas aeruginosa**

- **log CFU/ml**
- **time/days**
- **Arciolane 1300**
- **Arciolane 5500**
- **Oxane Hd**
- **Saline**
- **BHI**

Fig. 6. The effects of silicone oils, saline and GPB on the survival of *Candida albicans*.

![Graph showing antimicrobial activity of silicone oils on Candida albicans]

**Candida albicans**

- **log CFU/ml**
- **time/days**
- **Arciolane 1300**
- **Arciolane 5500**
- **Oxane Hd**
- **Saline**
- **GPB**
RESULTS

For *S. aureus*, growth inhibition was detected in the Oxane Hd silicone oil after 4 days, in Arciolane 1300 as well as in saline after 7 days, but in Arciolane 5500 after as many as 9 days. In the BHI enrichment medium, staphylococci were observed to survive for the whole 21 day period of testing (Fig. 1).

*S. epidermidis* was inhibited by the Oxane Hd oil as early as after 2 days of culture, by saline after 4 days, and by both Arciolane 1300 and Arciolane 5500 after 7 days. For the whole tested period, it was detectable in BHI (Fig. 2).

*E. faecalis* was not observed in the Oxane Hd silicone oil after 2 days, in saline after 4 days and in Arciolane 5500 after 9 days. Neither Arciolane 1300 nor BHI inhibited the growth capability of the enterococcus (Fig. 3).

The growth of *Bacillus* sp. was inhibited by the Oxane Hd oil after 9 days culture. In Arciolane 1300, Arciolane 5500, saline and BHI, it survived for the whole period of testing (Fig. 4).

The *P. aeruginosa* gram-negative rod was not observed in the Oxane Hd oil after 7 days, and in Arciolane 5500 after as many as 14 days. In the other media, i.e. Arciolane 1300, saline and BHI, it could be detected for the entire 21 day period (Fig. 5).

*C. albicans* was inhibited by the Oxane Hd silicone oil only after 14 days. It survived till the end of the test in Arciolane 1300, Arciolane 5500, saline and the GPB culture medium (Fig. 6).

Similarly, *A. fumigatus* was only inhibited by the Oxane Hd oil after 14 days incubation. The other tested and control media did not affect its ability to grow (Fig. 7).

In conclusion, the highest antimicrobial effect was observed for the Oxane Hd silicone oil in which the growth of the *S. epidermidis* and *E. faecalis* strains was not seen after only 2 days of culture, *S. aureus* after 4 days, *P. aeruginosa* after 7 days, Bacillus sp. after 9 days and *C. albicans* and *A. fumigatus* after 14 days. The remaining oils, Arciolane 1300 and Arciolane 5500, had only weak antibacterial and no antifungal effects. Survival of the individual microbes (in CFU/ml) in the tested types of silicone oil including control media is documented in Table 1. Rates of elimination of the microbes (in days) from the oils and control media are listed in Table 2.

DISCUSSION

Endophthalmitis always represents an extremely serious ophthalmologic finding, with the potential risk of loss of visual function. Patients may be also threatened by loss of the entire eye or even, if the infection penetrates the intracranial space, by death. Most commonly, exogenous endophthalmitis develops after intraocular surgery or penetrating eye injury.

The incidence after cataract surgery is reported to be between 0.07% and 0.58% \(\text{ref.}^{12-15}\). Sandvig \text{et al.}^{16} evaluated 111 cases of postoperative endophthalmitis, of which 80 (72%) were culture-positive. The detected etiologic agents were mostly (in 75 cases) gram-positive bacteria (coagulase-positive and -negative staphylococci, penicillin-resistant *S. aureus*) with *S. epidermidis* as the most frequent isolate (59%). Gram-negative rods were the second most frequent group of isolates (32%). In 12 cases, fungi were isolated (3%), yeast-like fungi in one case. In one case, a coagulase-positive staphylococcus was isolated from the vitreous humor. In one case, *P. aeruginosa* and *Aspergillus fumigatus* were isolated simultaneously, while in two cases, *Staphylococcus* spp. and *Candida* spp. were isolated simultaneously.
Table 1. Number of CFU/ml over time (days).

| Sample          | S. aureus | S. epidermidis | E. faecalis | Bacillus sp. | P. aeruginosa | C. albicans | A. fumigatus |
|-----------------|-----------|----------------|-------------|--------------|---------------|-------------|--------------|
| 02479 Arciolane 1300 | 2.2x10⁷    | 3.2x10⁴        | 4x10³       | 0            | 0             | 0           | 0            |
| 02479 Arciolane 5500 | 2.8x10⁷    | 1.4x10⁵        | 1.2x10²     | 0            | 0             | 0           | 0            |
| 02479 Oxane Hd     | 2.1x10⁷    | 3x10³          | 0           | 0            | 0             | 0           | 0            |
| 02479 BHI          | 3.4x10⁷    | 4.8x10⁴        | 5.8x10⁴     | 2.9x10⁴      | 4x10³         | 0           | 0            |
| 02479 GPB          | 3.6x10⁷    | 4.8x10⁴        | 1.5x10⁴     | 1.5x10⁴      | 1.5x10³       | 0           | 0            |
| Key: 0…growth inhibition *… growth, CFU count undetermined
Table 2. Time to elimination of bacteria in the tested samples (days).

| Sample         | *Staphylococcus aureus* | *Staphylococcus epidermidis* | *Enterococcus faecalis* | *Bacillus sp.* | *Pseudomonas aeruginosa* | *Candida albicans* | *Aspergillus fumigatus* |
|----------------|-------------------------|------------------------------|------------------------|----------------|--------------------------|--------------------|-----------------------|
| Arciolane 1300 | 7                       | 7                            | >21                    | >21            | >21                      | >21                | >21                   |
| Arciolane 5500 | 9                       | 7                            | 9                      | >21            | 14                       | >21                | >21                   |
| Oxane Hd       | 4                       | 2                            | 2                      | 9              | 7                        | 14                 | 14                    |
| saline         | 7                       | 4                            | 4                      | >21            | >21                      | >21                | >21                   |
| BHI/GPB        | >21                     | >21                          | >21                    | >21            | >21                      | >21                | >21                   |

In the treatment of endophthalmitis, intravitreal administration of antibiotics or PPV are often considered. Both the EVS (ref.13) and Aaaberg et al.12 concluded that there were no differences in results achieved by the two approaches. PPV is significantly more effective only in findings with uncertain light projection. Kaynak et al.9 in their retrospective study compared 24 eyes with postoperative endophthalmitis after cataract surgery that had vitrectomy as an initial procedure according to EVS criteria (core vitrectomy) with 28 eyes with postoperative endophthalmitis after cataract surgery that had total PPV, encircling band, silicone tamponade, and endolaser. They claimed that total PPV with buckling surgery, silicone tamponade and endolaser, increases the chance of surgical success and decreases the number of additional procedures in eyes with severe postoperative endophthalmitis. Yoon et al. reviewed the records of seven patients (10 eyes) with endogenous endophthalmitis who were followed for 6 months or longer. The patients were identified as having *Klebsiella pneumoniae* endogenous endophthalmitis. In most cases, the inflammation progressed within days and resulted in decreased vision worse than hand motions and a total vitreous abscess, despite systemic and intravitreal antibiotic injections. Yoon et al.10 observed better results in patients with early PPV with subretinal abscess drainage and silicone oil tamponade.

Ernest et al.17 recommended PPV for developing endophthalmitis, without previous intravitreal administration of antibiotics. They stated that early PPV prevented toxic damage of the retina and raised hope of maintaining favorable visual acuity of the affected eye. Immediate vitrectomy for endophthalmitis offers several advantages including removal of the infectious organisms and the toxins they produce, clearing of vitreous opacities, collection of abundant material for culture, removal of traction caused by condensed vitreous on the retina, and removal of inflammatory debris and bands over the ciliary body.

In the 1980s and 1990s, reports in the literature claimed that low-molecular-weight components, impuri-
ties commonly found in silicone oil, may display a certain toxicity. Because of their high volatility, some of these components may diffuse as vaporized molecules into the surrounding tissues, where they are thought to produce toxic effects. Inactivated catalyst remaining in the silicone oil may be toxic. Özdamar et al. were the first to notice and describe, under in vitro conditions, the antimicrobial activity of silicone oil with a viscosity of 1,300 cSt. Its antimicrobial effects were tested on agents more commonly responsible for endophthalmitis, namely the strains of S. aureus, S. epidermidis, P. aeruginosa, C. albicans and Aspergillus sp. The decrease and clearance of all agents was more rapid when cultured in silicone oil than in saline or culture media. The authors hypothesized that the antimicrobial effects of the oil, observed in vitro, could be due to either insufficient nutrients necessary for microbial growth, or its toxicity. An insufficient supply of nutrients would be expected to inhibit the growth and multiplication of the bacterial population, and may eventually lead to its death. However, nutrient insufficiency may also be considered in the case of saline, although saline potentially provides microbes not only with the necessary water but also other substances which enrich the solution after the natural disintegration of the inoculated agents. Özdamar et al. observed that microorganisms decreased more significantly in silicone oil than in saline and they assumed that its antimicrobial activity resulted from the toxicity of low-molecular-weight components.

The present study confirms the antimicrobial effects of silicone oils of different viscosity and specific gravity. Of the tested oils, Arclionole 1300, Arclionole 5500 and Oxane Hd, the most pronounced antimicrobial effects observed in vitro were those of the Oxane Hd heavy silicone oil. If all silicone oils represent an environment with insufficient nutrients for microbes, and yet there are differences in their antimicrobial effects, these may presumably result from their chemical composition, with potentially negative effects on a broader spectrum of microorganisms.

The question for further clinical examination remains whether Oxane Hd heavy silicone oil could be used in clinical practice to treat acute endophthalmitis. Based on in vitro tests it has the best antimicrobial activity. However, increased risk of inflammatory reaction in eyes with implanted heavy silicone oil has been discussed in the literature. Theelen et al. evaluated 19 eyes of 18 patients who underwent PPV and intraocular tamponade with high-density silicone oil Oxane HD. The indication for this type of intraocular tamponade was limited to cases with complicated retinal detachment of the inferior quadrants. One to eight weeks following PPV with high-density silicone oil, intraocular inflammation was found in 7 of 19 eyes (37%). The intraocular inflammatory signs completely resolved following removal of the high-density silicone oil. In contrast, Rizzo et al. used Oxane Hd heavy silicone oil in 28 patients who were operated on for recurrent retinal detachment with proliferative vitreoretinopathy (stage ≥C2) after vitreoretinal surgery, penetrating trauma and combined rhegmatogenous and choroidal detachment. No patient showed intraocular inflammation with Oxane Hd in situ. Heimann et al. in their review of 21 articles on the clinical use of 9 different heavy tamponades (fluorosilicone, C10F18, F6H8, OL62HV, Oxane Hd, O62, F6H8-silicone oil mixture, Densiron 68, and HWS 46-3000) concluded that the first generation (fluorinated silicone and perfluorocarbon liquids) and second generation (partially fluorinated alkanes) of heavy tamponades were associated with relatively high complication rates, for example, tamponade emulsification, intraocular inflammation, and rise in intraocular pressure. The complication spectrum of the new generation of heavy silicone oils (Oxane Hd, Densiron 68, and HWS 46-3000) seems to be comparable to conventional silicone oil tamponades.

CONCLUSION

The Oxane Hd silicone oil exhibited the highest antimicrobial activity, both antibacterial and antifungal. It inhibited the growth activity of all inoculated bacteria, albeit after various times; after 14 days, it acted upon candidas and aspergilli as well.

From this, it may be assumed that the various antimicrobial effects of different types of silicone oil are caused by their chemical composition. The results also suggest that, if endophthalmitis is treated by PPV, the application of silicone oil, in particular heavy silicone oil, into the vitreous cavity at the end of the surgery may contribute to the elimination of microorganisms from the intraocular space. However, given the potential risks and complications of inflammatory reactions in eyes with implanted heavy silicone oil discussed in the literature, clinical trials to confirm the safety of implanting heavy silicone oil Oxane Hd in the eye area in eyes with acute endophthalmitis are necessary.

ABBREVIATIONS

BHI, Brain Heart Infusion; CFU/ml, Colony-forming units in 1 ml; cSt, Centistokes; EVS, Endophthalmitis Vitrectomy Study; GPB, Glucose-Peptone Broth; H, Hours; PPV, Pars plana vitrectomy.

None of the authors has any proprietary interest.

REFERENCES

1. McCuen BW, Landers MB, Machemer R. The use of silicone oil following failed vitrectomy for retinal detachment with advanced proliferative vitreoretinopathy. Graefes Arch Clin Exp Ophthalmol 1986;224:339-9.
2. Abrams GW, Azen SP, McCuen BW 2nd, Flynn HW Jr, Lai MY, Ryan SJ. Vitrectomy with silicone oil or long-acting gas in eyes with severe proliferative vitreoretinopathy: results of additional and long-term follow-up. Silicone Study report 11. Arch Ophthalmol 1997;115:335-44.
3. Cairns JD, Campbell WG. Vitrectomy techniques in the treatment of giant retinal tears: a flexible approach. Clinical & Experimental Ophthalmology 1988;16:209-14.
1. Rizzo S, Genovesi-Ebert F, Belting C, Vento A, Cresti F. A pilot study on the use of silicone oil-RMN3 as heavier-than-water endotamponade agent. Graefes Arch Clin Exp Ophthalmol 2005;243:1153-7.

2. Tognetto D, Minutola D, Sanguinetti G, Ravalico G. Anatomical and Functional Outcomes after Heavy Silicone Oil Tamponade in Vitrectomical Surgery for Complicated Retinal Detachment: A Pilot Study. Ophthalmology 2005;112:1574.e1 - 1574.e8.

3. Castellarin A, Grigorian R, Bhagat N, Del Priore L, Zarbin MA. Vitrectomy with silicone oil infusion in severe diabetic retinopathy. Br J Ophthalmol 2003;87:318-21.

4. Heimann K, Dahl B, Dimopoulos S, Lennem KD. Pars plana vitrectomy and silicone oil injection in proliferative diabetic retinopathy. Graefes Arch Clin Exp Ophthalmol 1989;227:152-6.

5. Aras C, Ozdamar A, Karacorlu M, Ozkan S. Silicone oil in the surgical treatment of endophthalmitis associated with retinal detachment. Int Ophthalmol 2002;24:147-50.

6. Kaynak S, Öner FH, Koçak N, Cingil G. Surgical management of postoperative endophthalmitis: comparison of 2 techniques. J Cataract Refract Surg 2003;29:966-9.

7. Yoon YH, Lee SU, Sohn JH, Lee SE. Result of early vitrectomy for endogenous Klebsiella pneumoniae endophthalmitis. Retina 2003;23:366-70.

8. Isenberg HD. Clinical microbiology procedures handbook. Washington DC: ASM Press; 2004.

9. Aaberg TM, Flynn HW, Schiffman J, Newton J. Nosocomial bacterial endophthalmitis: Report of a ten-year retrospective study. Ophthalmology 1994;101:832-8.

10. Shadrer SK, Band JD, Lauter CB, Murphy P. The clinical spectrum of endophthalmitis. Incidence, predisposing factors, and features influencing outcome. J Infect Dis 1990;162:115-20.

11. Zhang YQ, Wang WJ. Treatment outcomes after pars plana vitrectomy for endogenous endophthalmitis. Retina 2005;25:746-50.

12. Schiedler V, Scott IU, Flynn HW Jr, Davis JL, Benz MS, Miller D. Culture-proven endogenous endophthalmitis: Clinical features and visual acuity outcomes. Am J Ophthalmol 2004;137:725-31.

13. Wong JS, Chan TK, Lee HM, Chee SP. Endogenous bacterial endophthalmitis. An east Asian experience with Klebsiella pneumoniae infection. Retina 2004;24:383-90.

14. Nakamura K, Refojo MF, Crabtree DV, Pastor J, Leong FL. Ocular toxicity of low-molecular-weight components of silicone and fluoro silicone oils. Invest Ophthalmol Vis Sci 1991;32:3007-20.

15. Gabel VP, Kampik A, Burkhardt J. Analysis of intraocularly applied silicone oils of various origins. Graefes Arch Clin Exp Ophthalmol 1987;225:160-2.

16. Lehmna LA J, Thompson LP, White LO, Keys MF, Campbell MJ. Half-life of intracameral gentamicin after phacoemulsification. J Cataract Refract Surg 1997;23:83-8.

17. Norregaard JC, Thoning H, Bemth-Petersen P, Andersen TF, Javitz JC, Anderson GF. Risk of endophthalmitis after cataract extraction: results from the International cataract surgery outcomes study. Br J Ophthalmol 1997;81:102-6.

18. Sandvig KU, Dannevig L. Postoperative endophthalmitis: Establishment and results of a national registry. J Cataract Refract Surg 2003;29:1273-80.

19. Paet L, Isenberg SJ, Yoshimori R, Chang A, Lam GC, Wachler B, Neumann D. The effect of povidone-iodine solution applied at the conclusion of ophthalmic surgery. Am J Ophthalmol 1995;119:701-5.

20. Arsan A, Aksen A, Duman S, Aslan B, Kocak I. Acute endophthalmitis outbreak after cataract surgery. J Cataract Refract Surg 1996;22:1116-20.

21. Doft BH, Kelsey SF, Wisniewski S, Metz DJ, Lobes L, Rinkoff J, Davis M, Kassoff A. Treatment of endophthalmitis after cataract extraction. Retina 1994;14:297-304.

22. Endophthalmitis vitrectomy study group. Microbiologic factors and visual outcome in the endophthalmitis vitrectomy study. Am J Ophthalmol 1996;122:830-46.

23. Speaker MG, Menikoff JA. Prophylaxis of endophthalmitis with topical povidone-iodine. Ophthalmology 1991;98:1483-91.

24. Jackson TL, Eyken SJ, Graham EM, Stanford MR. Endogenous bacterial vitrectomy study group. Microbiologic factors and of intravenous antibiotics for the treatment of postoperative endophthalmitis. J Infect Dis 1990;162:115-20.

25. Zhang YQ, Wang WJ. Treatment outcomes after pars plana vitrectomy for endogenous endophthalmitis. Retina 2005;25:746-50.

26. Schiedler V, Scott IU, Flynn HW Jr, Davis JL, Benz MS, Miller D. Culture-proven endogenous endophthalmitis: Clinical features and visual acuity outcomes. Am J Ophthalmol 2004;137:725-31.

27. Wong JS, Chan TK, Lee HM, Chee SP. Endogenous bacterial endophthalmitis. An east Asian experience with Klebsiella pneumoniae infection. Retina 2004;24:383-90.

28. Nakamura K, Refojo MF, Crabtree DV, Pastor J, Leong FL. Ocular toxicity of low-molecular-weight components of silicone and fluorosilicone oils. Invest Ophthalmol Vis Sci 1991;32:3007-20.

29. Gabel VP, Kampik A, Burkhardt J. Analysis of intraocularly applied silicone oils of various origins. Graefes Arch Clin Exp Ophthalmol 1987;225:160-2.

30. Ozdamar A, Aras C, Ozturk R, Akin E, Karacorlu M, Erçikan C. In vitro antimicrobial activity of silicone oil against endophthalmitis-causing agents. Retina 1999;19:122-6.

31. Theelen T, Tilen MA, Klevering BJ. Intraocular inflammation following endotamponade with high-density silicone oil. Graefes Arch Clin Exp Ophthalmol 2004;242:617-20.

32. Heimann H, Staappler T, Wong D. Heavy tamponade 1: a review of indications, use, and complications. Eye 2008;22:1342-59.