CLINICAL SCIENCE

Measurement of axial length of eyes with incomplete filling of silicone oil in the vitreous cavity using *x* ray computed tomography

Kazuo Takei, Yasuo Sekine, Fumiki Okamoto, Sachiko Hommura

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See end of article for authors' affiliations

Correspondence to: Kazuo Takei, MD, Department of Ophthalmology, Institute of Clinical Medicine, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba-shi, Ibaraki-ken 305-8575, Japan; ktakei@md.tsukuba.ac.jp

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Aims: To establish a reliable method for measuring the axial length of the eye with incomplete filling of silicone oil in the vitreous cavity in order to determine the IOL power before executing combined cataract surgery and silicone oil removal.
Methods: 12 eyes of 12 patients undergoing combined cataract extraction and silicone oil removal between October 1998 and June 2000 were entered prospectively into this study. All eyes were examined using an *x* ray computed tomography (CT) scanner. Each axial length of a silicone oil injected eye was measured on the best CT slice among eyeball cuts, which showed both the insertions of the medial and lateral rectus muscle, the thickest slice of the lens, and the optic nerve. The IOL power for the eyes was determined using the SRK/T formula based on the CT data. The deviation of postoperative refraction from the goal refraction was evaluated for each eye.
Results: The CT slices demonstrated that the vitreous cavity was not completely filled with the oil in all of the silicone oil injected eyes. The deviation of postoperative refraction from the goal refraction was less than 1 dioptre (D) error in six of 12 eyes (50%), and was less than 2 D error in nine eyes (75%). In the other three eyes having more than 2 D error, the axial length was 27 mm or more.
Conclusion: The CT measurement of axial eye length for determining IOL might be a useful method for evaluating silicone oil injected eyes before combined cataract surgery and silicone oil removal.

Recent reports have shown that combined cataract surgery and silicone oil removal is a useful procedure for patients with a history of retinal detachment repair requiring silicone oil placement in whom a clinically significant cataract subsequently developed.[1–4] Previous studies have shown methods for intraocular lens (IOL) power determination in an oil filled eye using A-mode echography in the combined procedure.[4 5] The presumption that the vitreous cavity is completely filled by the silicone oil was essential for converting the measured axial eye length (AL) in the presence of silicone oil to the true AL in these reports. However, a space not filled with oil is observed in most silicone oil injected eyes to a greater or lesser extent. The space occurs because it is difficult to completely remove the vitreous body behind the lens without intraoperative cataract formation or progression, and there is a high risk of postoperative elevation of the intraocular pressure in the case of filling the vitreous cavity completely with the silicone oil. Accordingly, the reliability of the calculated AL using A-mode echography depends on the volume of the space in the vitreous cavity that is not filled with oil.

In this report, we present a direct *x* ray method for measuring the AL independent of the silicone oil volume for determining the IOL power before executing the combined surgery.

CASE REPORTS

We encountered a case demonstrating potential sources of error in calculating AL from A-mode echography before the *x* ray computed tomography (CT) case series.

A 32 year old woman underwent pars plana vitrectomy and silicone oil injection for her right proliferative vitreoretinopathy in our hospital. After the surgery, we found an obvious interface between the silicone oil and the vitreous humour inferiorly in the vitreous cavity by indirect ophthalmoscopy with the patient sitting upright. The vitreous findings raised the question of whether a simple conversion factor for determining actual AL reported in oil filled eyes could be applied to the oil unfilled eye and that combined cataract surgery and silicone oil removal should be performed later. Then we recorded both A-mode and B-mode echograms of the eye employing a 10 MHZ transducer with the patient supine, sitting, and prone. The echograms distinctly showed an oil unfilled space in front of the macular area (Fig 1). The space was largest when patients were in the supine position, decreased when they were sitting upright, and absent when they were in the prone position. Additionally, the anterior silicone oil surface was clearly shown not to be in contact with the posterior lens surface when patients were in the sitting upright position (Fig 1, middle right). These findings caused us to abandon the method using A-mode echogram with the conversion factor to determine the AL of the oil unfilled eyes. We then began a direct *x* ray method for measuring the AL independent of the silicone oil volume for calculating the IOL power before executing the combined surgery.

Twelve eyes of 12 consecutive patients undergoing combined cataract extraction and silicone oil removal between October 1998 and June 2000 were measured using *x* ray CT. The age of the patients ranged between 31 and 72 years (mean 54.2 (SD 10.1) years). The reasons for pars plana vitrectomy were proliferative vitreoretinopathy (n = 6) in eyes after failed primary buckling procedures or in eyes with longstanding rhegmatogenous detachment; proliferative diabetic retinopathy with persisting vitreous haemorrhage (n = 4); and macular hole with retinal detachment (n = 2). Pars plana vitrectomy with an ocular endotamponade of silicone oil at a specific gravity of 1000 centistokes (cS) had been performed 2–32 months before removal of the silicone oil. The injected volume of silicone oil ranged from 4.0 to 6.0 ml (mean 4.6 (0.6) ml). In all patients, the retina was attached before removal of the silicone oil.

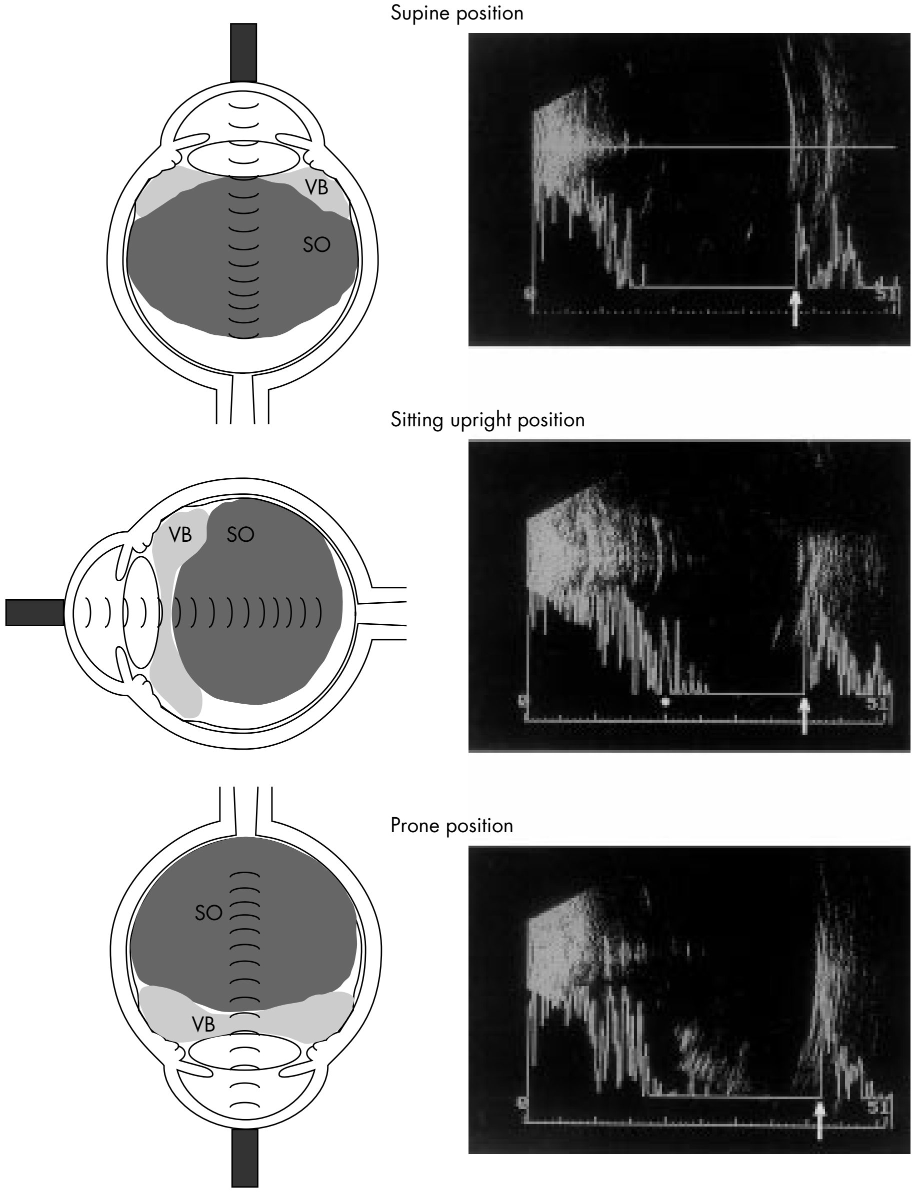

Figure 1 Ultrasonograms of a silicone oil injected eye with the patient in supine, sitting, and prone positions. Silicone oil migrates upward in the vitreous cavity. The end of the silicone oil bubble was clearly observed (↑) in each position. The space not filled with oil in front of the retina was largest when patients were in the supine position, decreased when they were sitting upright, and absent when they were in the prone position. Additionally, the anterior silicone oil surface (*) was clearly shown not to be in contact with the posterior lens surface when patients were in the sitting upright position. SO = silicone oil; VB = vitreous body.

All patients were examined in supine position with a CT scanner (GE 9800 HiLight Adv, Milwaukee, WI, USA). Scanning time was 3.0 seconds; a 512 × 512 matrix was displayed. Both the slice thickness and the increment were 3.0 mm. The CT slices were taken parallel to the plane including the corneal apex and the optic nerve by tilting the gantry from the position of the orbitomeatal line. The patient was instructed to look straight ahead during each scanning period. The AL of each silicone oil injected eye was measured using a diagnostic console on the best CT slice among the eyeball cuts, which showed both of the insertions of the medial and lateral rectus muscle, the thickest slice of the lens, and the optic nerve. Except for two patients with posterior staphyloma, the AL was obtained as the distance between the corneal apex and the normal foveal position (approximately 4.5 mm temporal to the centre of the optic disc). For the two patients with posterior staphyloma, the AL was determined by measuring the distance between the corneal apex and the centre of the staphyloma. When there was incomplete filling of the vitreous cavity by the silicone oil, we also measured two distances, in front and behind the silicone oil on the axial line—that is, the distance from the posterior lens surface to the anterior silicone oil surface (distance lens-silicone, DLS in Fig 2A) and the distance from the posterior silicone oil surface to the retina (distance silicone-retina, DSR in Fig 2A) for the purpose of demonstrating clearly the significance of the oil unfilled space in the vitreous cavity.

There are seven eyes with a measured AL less than 27.0 mm and five eyes with an AL greater than or equal to 27.0 mm. In 11 of 12 silicone oil injected eyes, the vitreous cavity was clearly divided into three areas of different density—namely, the residual vitreous body behind the lens, the silicone oil, and the vitreous humour (Fig 2A). The DLS ranged from 0.6 to 1.2 mm (mean 0.8 (0.2) mm). The DSR ranged from 0 to 7.6 mm (mean 2.4 (1.4) mm).

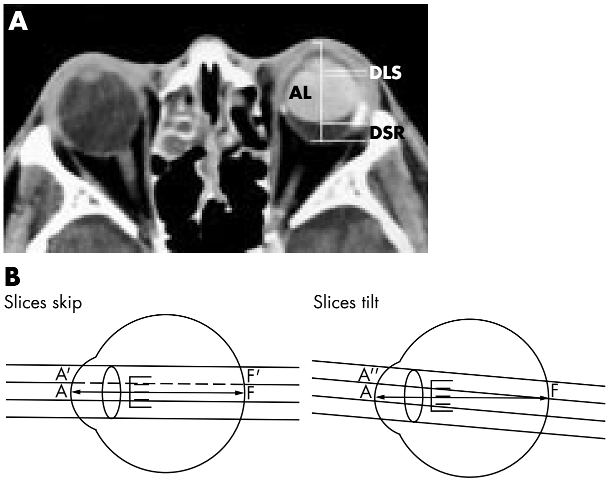

Figure 2 (A) The mid-ocular CT slice of a silicone oil injected eye, which shows the vitreous cavity being not filled with the oil and clearly divided into three areas of different density—namely, the residual vitreous body behind the lens, the silicone oil, and the vitreous humour. The AL (axial length), DLS (distance lens-silicone), and DSR (distance silicone-retina) are easily measured on the slice. (B) Schemata representing two error patterns in measuring the AL using x ray CT. Left schema: the measured axis shifts parallel to the true axis. The CT slices skip over the plane including the true axis. Right schema: the measured axis tilts from the true axis. AF and A′F′ indicate the true and the measured axis respectively.

All but one eye had implantation of an IOL. One eye received no IOL implantation because the calculated IOL power for goal refraction was approximately 0 dioptre (D). Selection of the IOL type was based on surgeon preference; eight of 12 eyes received a convex plano IOL composed of poly(methylmethacrylate), and three received a biconvex acryl IOL. The IOL power for the eyes was computed by a ultrasonic biometric instrument (Ophthalmic Image 2000 A/B Scan System, Mentor Ophthalmics, NA); the SRK/T formula was applied to all eyes.

Using procedures similar to those described in previous reports,[1–4] we performed silicone oil removal through a planned posterior capsulotomy after phacoemulsification in nine eyes and after extracapsular cataract extraction in three eyes.

In each patient, the postoperative refraction was determined using the best spectacle correction with reference to the objective refractive error obtained using an auto keratorefractor (Topcon KR-7100, Tokyo, Japan) at least 3 months after surgery and compared with the goal refraction using the spherical equivalent in dioptres (D). The deviation from the goal refraction was calculated for each eye (postoperative refraction minus the refraction predicted by the SRK/T formula).

The deviation from the goal refraction ranged from −2.84 to 1.64 D (mean −0.27 (1.59) D). Six of 12 eyes (50%) had less than 1 D error, and nine eyes (75%) had less than 2 D error. In all of the three eyes having more than 2 D error, the axial length was 27 mm or more.

DISCUSSION

Silicone oil has been used increasingly as a retinal tamponade for anatomical reattachment of the retina in patients with complex retinal detachments. Current prospective observational studies showed not only its effectiveness in the management of complex retinal detachments associated with multiple aetiologies but also a high incidence of cataract formation or progression in phakic eyes.[6–14] Phacoemulsification and silicone oil removal through a single corneal incision was recently reported to be a safe and effective surgical procedure for the management of postoperative cataract and intravitreous silicone oil.[1–4]

To determine IOL power in an oil filled eye using A-mode echographic data, previous studies showed a conversion factor of 0.64, which is a calculated ratio of the speed of sound (987 m/s) in silicone oil with 1000 cS viscosity to that (1532 m/s) in vitreous humour.[4 5] However, since retinal surgeons work to avoid an excessive intravitreal injection of silicone oil, which can cause secondary glaucoma in the early postoperative period, the interface between the silicone oil and the vitreous humour is frequently observed inferiorly in the vitreous cavities with the patient sitting upright. Also, surgeons know that they cannot perform complete removal of the vitreous body behind the lens without intraoperative cataract formation or progression.

Although this is not a comparative report of the predictability of CT scan and ultrasonography, we recorded ultrasonograms of a silicone oil injected eye with the patient in supine, sitting, and prone positions before *x* ray CT measurement. As shown in Figure 1, silicone oil migrates upwards because of its lower relative density compared to the fluid in the vitreous cavity—its floatation force. Accordingly, the space not filled with oil in front of the macular area was largest when patients were in the supine position, decreased when they were sitting upright, and absent when they were in the prone position. Additionally, the anterior silicone oil surface was clearly shown not to be in contact with the posterior lens surface when the patient were in the sitting upright position. The values of the DLS and DSR indicated that the space not filled with oil varies in extent, depending on the volume of the injected silicone oil and residual vitreous body in the operated eyes.

On the other hand, the accuracy of the AL measured on a CT slice depends on the amount of discrepancy between the true and measured axis of the eye. We estimated errors in measurement of the axis on the CT slice using Gullstrand's No 1 schematic eye. If a measured axis shifted parallel 1.5 mm (one half of the slice thickness) upward or downward from the true axis, the measured axis is approximately 0.24 mm shorter than the true axis (Fig 2B, left). If the measured axis tilted 5 degrees from the true axis, the former is approximately 0.19 mm shorter than the latter (Fig 2B, right). In this study the SRK/T calculated IOL power was actually greater than required in three of five longer eyes (⩾27.0 mm), suggesting that the AL had been underestimated by the CT scanning technique. This phenomenon may be due to slices skip or slices tilt as demonstrated in Figure 2B. The actual error in measuring the axial length using *x* ray CT cannot be evaluated, but the deviation of actual postoperative refraction from predicted refraction could represent the accuracy of the measurement. Compared with previous studies regarding the accuracy of the SRK/T formulas,[15–17] the deviation from the goal refraction in this report might be acceptable. Furthermore, the mean value of the deviation in this report appears to be smaller than the literature of biometry of the silicone oil filled eye.[5] Although there have been some reports regarding measurement of the eyeball using *x* ray CT,[18 19] few studies showed AL for determining IOL power. The accuracy of AL measurement would improve with a CT slice thickness of less than 3 mm which requires the patient to be exposed to much larger amount of irradiation to obtain sufficient contrast resolving power. As a result of the accuracy of refraction obtained in this study, we believe that the 3 mm slice thickness is useful for determining the AL. Although the direct *x* ray method of determining the AL of the eye first employed by Rushton[20] has been superseded by ultrasonic techniques, the treatment of oil injected eyes might require the *x* ray CT measurement shown in this report.

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Authors' affiliations

K Takei, Y Sekine, F Okamoto,S Hommura, Department of Ophthalmology, Institute of Clinical Medicine, University of Tsukuba, Ibaraki, Japan

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