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

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: Twelve eyes of 12 patients undergoing combined cataract extraction and silicone oil removal between October 1998 and June 2000 were measured. All eyes were examined using 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.5–7 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.
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 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.
tem, Mentor Ophthalmics, NA); the SRK/T formula was biometric instrument (Ophthalmic Image 2000 A/B Scan Sys-

eight of 12 eyes received a convex plano IOL composed of 

Selection of the IOL type was based on surgeon preference; 

power for goal refraction was approximately 0 dioptre (D). 

received no IOL implantation because the calculated IOL 

all of the three eyes having more than 2 D error, the axial 

1.64 D ( mean 

surgery and compared with the goal refraction using the 

objective refractive error obtained using an auto keratorefrac-

tion and silicone oil removal through a single corneal incision 

Multiple aetiologies but also a high incidence of cataract 

management of complex retinal detachments associated with 

Silicone oil has been used increasingly as a retinal tamponade 

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 Sys-

tem, Mentor Ophthalmics, NA); the SRK/T formula was applied to all eyes.

Using procedures similar to those described in previous 

reports,14 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 deter-

mined using the best spectacle correction with reference to the 

objective refractive error obtained using an auto keratorefrac-

tor (Topcon KR-7100, Tokyo, Japan) at least 3 months after 

surgery and compared with the goal refraction using the 

spherical equivalent in dioptries (D). The deviation from the 

gain 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 observa-

tional 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.15–17 Phacoemulsi-

fication and silicone oil removal through a single corneal incision 

was recently reported to be a safe and effective surgical proce-

dure for the management of postoperative cataract and intra-

vitreous silicone oil.18

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.19–21 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 cavi-

ties 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 predictabil-

ity of CT scan and ultrasonography, we recorded ultrasono-

grams 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—it’s 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 pre-

dicted refraction could represent the accuracy of the measure-

ment. Compared with previous studies regarding the accuracy 

of the SRK/T formulas,10–17 the deviation from the goal refrac-

tion 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. 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 

Rushoton20 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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REFERENCES


