# Ultrasound velocity in heavy ocular tamponade agents and implications for biometry.

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**Abstract:**

**Purpose:**

Heavy ocular tamponade agents are shown to be an effective tamponade in complicated retinal detachments. Combined oil removal and cataract surgery may be performed and ultrasound (US) provides a reliable means to measure the axial length of eyes. The aim of study was to evaluate the velocity of US in various tamponade agents.

**Methods:**

Five tamponade agents (SO 1000, SO 5000, Oxane HD, Densiron 68, and F-Decalin) were studied in vitro. Time of flight ($T_1$) was measured between an ultrasound transducer and the bottom of a container of the agent, and remeasured ($T_2$) after reducing the separation by 1 cm. The speed of sound in the particular material was calculated from the difference between $T_2$ and $T_1$. Measurements were repeated over a range of temperatures from 18 - 42°C.

**Results:**

The speed of sound at 37°C ranged from 645±8 m/s to 976±10 m/s depending on the tamponade agent. In Densiron 68 and F-Decalin, the speed of sound was markedly reduced to 914±10 m/s and 645±8 m/s respectively. The temperature dependence of speed of sound varied between -2.2 and -3.6 m/s/°C depending on the particular oil. With 95% confidence, the true speed is believed to lie within ± 5m/s of these values. The deviation from intended refraction was between 0.38 to 30.15 dioptres depending on the tamponade agent by using correction factor (CF) for SO 1000cs.

**Conclusions:**

Variability in the velocity of US should be taken into account when performing biometry. Biometry machines should be adjusted for various tamponade media when calculating IOL power.

## Introduction:

Heavy silicone oil is an important adjunct to treat complicated retinal detachments including rhegmetogenous retinal detachments with large inferior retinal breaks and proliferative vitreoretinopathy (PVR).[1] Cataract development or progression of already existing cataract is a known complication of conventional silicone oil and heavy silicone oil. [2,3] In case of accelerated cataract formation during the oil tamponade period a combined oil removal and lens extraction followed by the implantation of an intraocular lens (IOL) is desirable. Therefore, a precise biometry is required for IOL power calculation even in oil filled eyes, especially if the original vitreo-retinal disorder did not allow for accurate biometry prior to the tamponade use.

Ultrasound (US) biometry can be performed in silicone oil-filled eyes but the speed of sound is slower hence the axial length (AL) appears longer in silicone oil filled compared to vitreous filled eyes. This issue can be addressed by employing a conversion factor (CF) to ascertain the true AL of an eye.[4] As far as we know there are no studies looking at the speed of sound in the heavy ocular tamponade agents.

The primary aim of our study was to evaluate velocity of US in heavier ocular tamponade agents. We also aimed to estimate CF for these agents and to determine the potential impact of using CF for conventional silicone oil (SO) 1000 cSt on postoperative refraction.

## Methods:

We included five tamponade agents; silicone oil (SO) 1000 cSt , SO 5000 cSt (Medicel AG, Widnau, Switzerland), Oxane HD (Bausch & Lomb, Toulouse, France), Densiron 68 (Fluoron Co, Neu-Ulm, Germany)and F-Decalin (Fluoron Co, Neu-Ulm, Germany) and measured speed of sound in these materials in vitro. An US transducer (Panametrics model 5052PR; centre-frequency 5MHz) was used to measure the speed (Figure 1). Although a higher frequency than 5MHz is used for biometry, ultrasound velocity is regarded as being non-dispersive in most media, so these measurements should not be affected by frequency. Time of flight ($T_1$) was measured between the transducer and bottom of the container and remeasured ($T_2$) after reducing the separation by 1 cm. The speed of sound in the particular material was calculated from the difference between $T_2$ and $T_1$. All measurements were repeated over a temperature range of 18-42°C. The system was validated for water. The speed of sound in water was measured as 1487±10 m/s at 22$^o$ C and 1482.8 ±10 m/s at 20$^o$ C, whereas the true values are 1488 and 1482 respectively. We calculated CF of tamponade agent using this formula:

Conversion factor (CF) = Speed of sound in tamponade agent/ Speed of sound in vitreous humour

Where speed of sound in vitreous humour = 1532 m/s [5]

We also calculated deviation from intended refraction if the standard CF for SO 1000 cSt was used in biometry for IOL power estimations.

**Results:**

The speed of sound ranged from 645±8 m/s to 976±10 m/s depending on the tamponade agent. However in case of heavy ocular tamponade agents there were significant differences in the speed. In Densiron 68 and F-Decalin, the speed of sound was markedly reduced to 914±10 m/s and 645±8 m/s respectively (Table 1). The temperature dependence of speed of sound varied between -2.2 and -3.6 m/s/°C depending on the particular oil (Figure 2). With 95% confidence, the true speed is believed to lie within ± 5m/s of these values. The CF was calculated for these agents that ranged from 0.421 to 0.637 (Table 1). The deviation from intended refraction was between 0.38 to 30.15 dioptres depending on the tamponade agent by using CF for SO 1000cs (Table 2).

**Table 1: It shows speed of ultrasound in different ocular tamponade agents and their conversion factors.**

| **Type of silicone oil** | **Speed (m/s) at 37°C** | **Conversion factor** |
|---|---|---|
| SO 1000 | 976±10 | 0.637 |
| SO 5000 | 970±10 | 0.633 |
| Oxane HD | 930±10 | 0.607 |
| Densiron 68 | 914±10 | 0.597 |
| F-Decalin | 645±10 | 0.421 |

**Table 2: It illustrates axial length (AL) measurements of various ocular tamponade agents and impact of using conversion factor for SO1000 on AL and refraction if we assume theoretical AL of 23.5mm.**

| **Oil** | **AL measurements (mm)** | | **Error** (***) | |
|---|---|---|---|---|
| | **$AL_{SO}$** (**) | **Adjusted with $CF_{SO1000}$** | **AL (mm)** | **Refraction (D)** |
| SO 1000 | 36.89 | 23.5 | 0.00 | 0.00 |
| SO 5000 | 37.12 | 23.65 | 0.15 | 0.38 |
| Oxane HD | 38.71 | 24.66 | 1.16 | 2.9 |
| Densiron 68 | 39.36 | 25.07 | 1.57 | 3.93 |
| F-Decalin | 55.82 | 35.56 | 12.06 | 30.15 |

(**) Calculated AL of tamponade filled eye when no CF was used.

(***) Errors in true AL measurements and desired refraction if $CF_{SO1000}$ was used for other tamponade agents.

**Discussion:**

Heavy ocular tamponade agents differ significantly in their ability to make contact with the inner surface of the vitreous cavity, which is determined by their specific gravity and interfacial tensions, and their viscosity and is critical to maintain the integrity of the tamponade over a longer period of time.[6] In recent years, a marked decrease in the complication rate and an improvement in the anatomical and functional outcomes could be achieved with the introduction of new heavy tamponades, in particular new heavy silicone oils.[7] Measurement of AL can be challenging in eyes filled with heavy tamponade agents. There are different techniques that can be utilised to measure AL in the eyes filled with heavy tamponade agents. Recently Roessler et al have shown accuracy and reproducibility of AL measurement in the eyes filled with conventional silicone oil and heavy silicone oil by using partial coherence laser interferometry (PCI).[8] In few studies reliable AL measurements in silicone oil-filled eyes or incomplete silicone oil-filled eyes were determined by using magnetic resonance imaging and x-ray computed tomography. [9,10] Although PCI can give reliable and accurate biometry estimations in normal eyes, it has limitations in patients with dense cataracts, corneal scarring and emulsified oil.[11] Other option is intraoperative biometry by A-scan US, following removal of heavy silicone oil. This method has shown comparable postoperative refractive results to PCI for eyes filled with silicone oil.[12] Issues about sterilization of the biometry machine and prolongation of the operative procedure are likely to limit its benefits.

Preoperative US biometry can achieve accurate IOL power calculations in cases of heavy ocular tamponade agents if the velocity of US beam in these agents is known. A CF can then be calculated and inserted in the formula. Our study shows a significant reduction in speed of sound in heavy tamponade agents that can lead to an error in predicted AL from 1.16 mm to 12.06 mm (if a CF of standard SO 1000 cSt is used).

In terms of refractive outcomes, the predicted refraction can vary between 2.9 D and 30.15 D with same CF depending on the tamponade agents. Murray et al have demonstrated accurate prediction of required IOL power with US biometry by using CF of 0.71 for conventional SO 1300 cSt and their mean difference in actual and predictive refractive target was 0.74 to 1.31 D depending on placement of IOL.[13] By using the CF values for the specific tamponade agents we can avoid refractive surprises. Our study findings are derived from an in vitro model and further studies are required to test the accuracy of these CF values in clinical practice.

It is important to take into account the variability in velocity of US in different tamponade agents when performing biometry. US machines should be adjusted for various heavy ocular tamponade agents when calculating IOL power.

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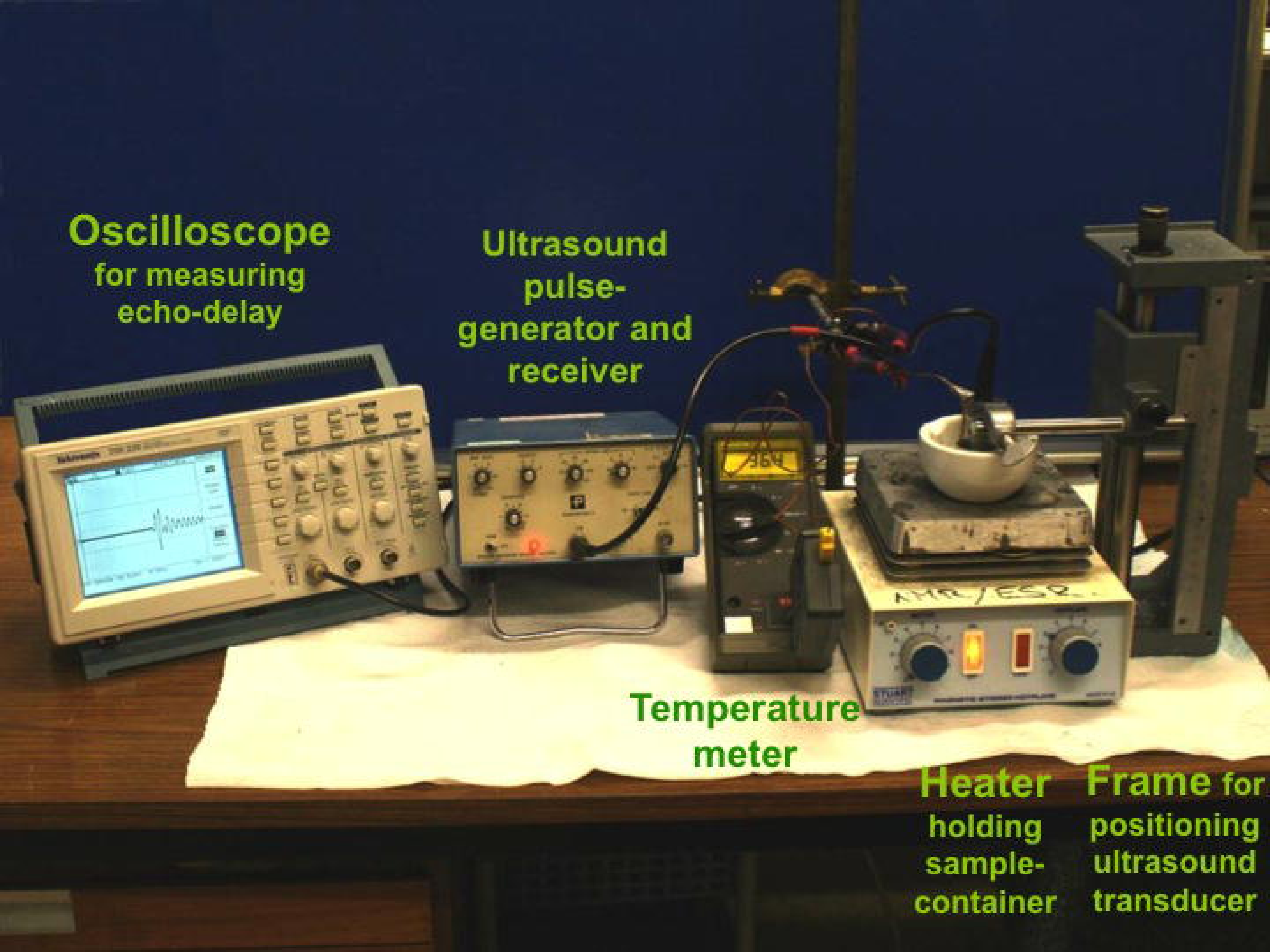
**Legends:**

Figure 1: It describes various instruments used in measuring speed of sound in ocular tamponade agents.

Figure 2: It shows speed of sound in different ocular tamponade agents and variation in speed depending on the temperature.


Oscilloscope
for measuring
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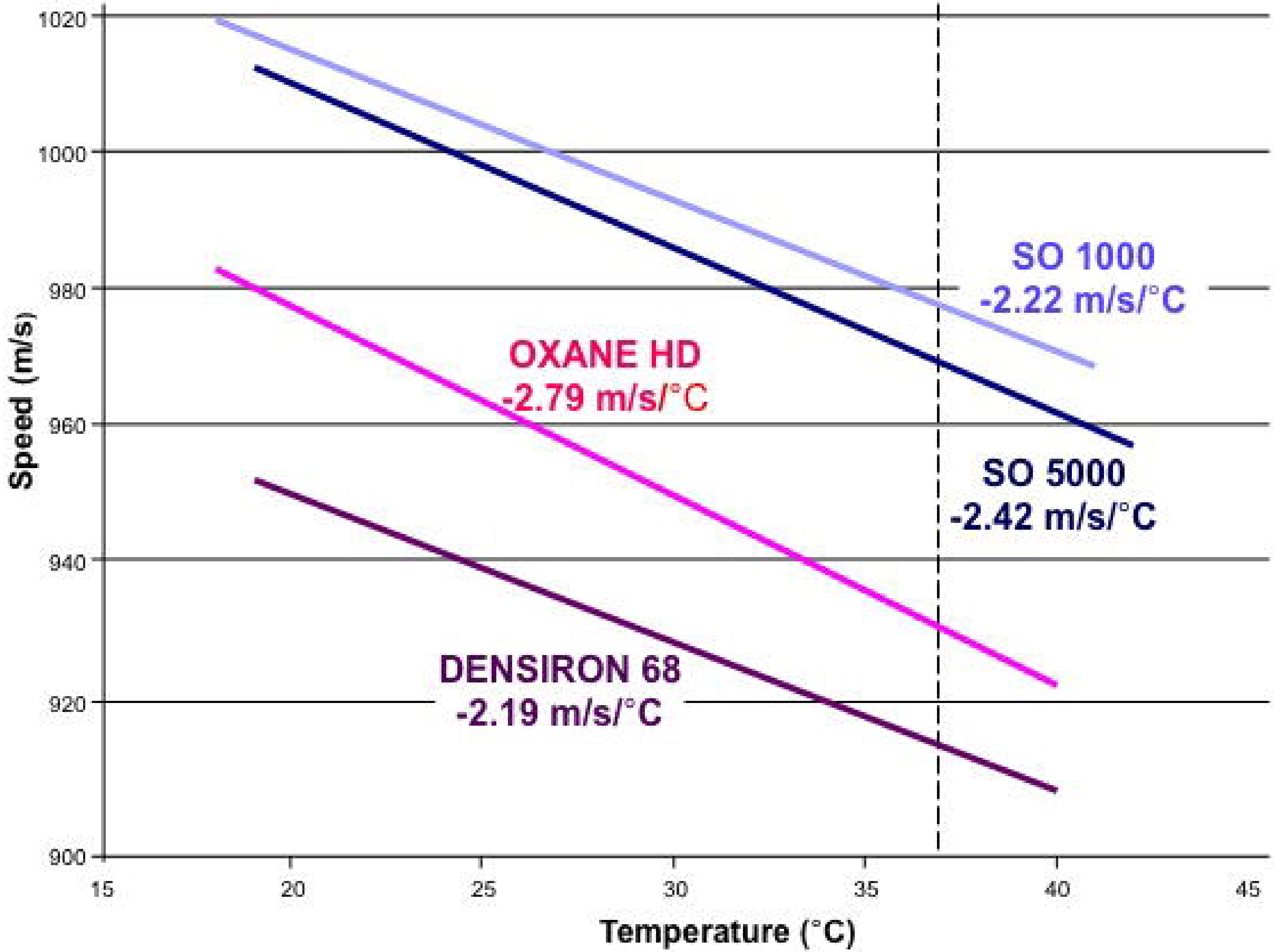

1020
1000
980
960
940
920
900
Speed (m/s)
15
20
25
30
35
40
45
Temperature (°C)
SO 1000
-2.22 m/s/°C
OXANE HD
-2.79 m/s/°C
SO 5000
-2.42 m/s/°C
DENSIRON 68
-2.19 m/s/°C