Changes in Vitreous Temperature During Intravitreal Surgery

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PURPOSE. To determine how different intraoperative surgical procedures affect the midvitreous temperature.

METHODS. The vitreous temperatures were monitored continuously with an intravitreal thermocouple in 87 eyes of 81 cases undergoing vitrectomy. Thirty-three eyes had diabetic retinopathy (DR), 35 eyes had an epiretinal membrane, and 19 eyes had an idiopathic macular hole. In eyes with DR, the correlation between the number of photocoagulations (PCs) and the change in temperature was analyzed. The temperature was also recorded before and after combined phacoemulsification and aspiration (PEA) and vitrectomy in 10 eyes.

RESULTS. The average midvitreous temperature before the vitrectomy was 33.0 ± 1.3°C, 30.7 ± 1.7°C after core vitrectomy, 32.9 ± 1.3°C after membrane peeling, and 29.2 ± 1.4°C after peripheral vitrectomy. The temperature before PC was 29.8 ± 1.5°C, and it increased to 31.5 ± 1.9°C post-PC. The differences in the temperatures between consecutive procedures were significant (P < 0.01, respectively, Wilcoxon signed-rank test). The difference in the temperatures of the same procedures among the different diseases was not significant except after membrane peeling. A significant correlation was detected between the number of PCs and the duration of the PCs, and between the duration of PCs and the change in vitreous temperature after PC (r = 0.719, P = 0.0010, and r = 0.800, P = 0.0002, respectively, Spearman’s rank correlation coefficient test). The temperature after PEA decreased significantly by 2.5°C.

CONCLUSIONS. Our results showed that vitreous temperatures vary during different vitrectomy procedures. Keywords: thermocouple, vitreous temperature, vitreous surgery

The temperature of the vitreous has been investigated quite extensively in animal experiments.1–3 Recently, the temperature of the midvitreous was recorded during vitrectomy in six patients by Landers et al.4 The temperature in the vitreous cavity was measured, and they reported that the temperature decreased after core vitrectomy and increased after the completion of vitrectomy. However, serial changes of the intravitreal temperature during the different vitrectomy procedures have not been reported.

The purpose of this study was to determine the intravitreal temperatures during different procedures of vitrectomy. In addition, we examined whether the temperature variations were different for different diseases, and we also measured the temperature before and after the removal of the crystalline lens during combined cataract surgery and vitrectomy.

METHODS

Patients

We studied 87 eyes of 81 consecutive patients undergoing vitrectomy by a single surgeon (HT) between October 2009 and June 2011 at the Nagoya University Hospital. The procedures used for this study were approved by the Ethics Committee of the University Hospital, and an informed consent was obtained from all patients after an explanation of the procedures to be performed. All of the procedures conformed to the tenets of the Declaration of Helsinki.

Forty-seven of the patients (51 eyes) were men and 34 patients (36 eyes) were women. The average age of the patients was 62.8 ± 11.6 years with a range from 28 to 83 years. Thirty-three eyes of 29 patients had diabetic retinopathy (DR), 10 eyes of seven patients had diabetic macular edema (DME) in eyes with proliferative diabetic retinopathy (PDR), and 25 eyes of 22 patients underwent vitrectomy for PDR. Thirty-five eyes of 34 patients had an epiretinal membrane (ERM), and 19 eyes of 18 patients had an idiopathic macular hole (MH).

The vitreous temperature was monitored intraoperatively during the entire surgery until the time of fluid-air exchange in all 87 eyes. The temperature recorded just after each procedure was used to represent the temperature during that procedure (Table 1). The duration of the procedures was obtained retrospectively from the charts and used for the analyses.

Surgical Procedures

Vitrectomy was performed after retrobulbar anesthesia by 5 mL of 2% lidocaine + 0.5% xylocaine. A 23-gauge or 25-gauge of Accurus Vitrectomy System (Alcon, Fort Worth, TX, USA) was used for the vitrectomy, and 68 eyes underwent combined...
phacoemulsification and aspiration (PEA) and vitrectomy and 19 eyes underwent vitrectomy alone. Six eyes were pseudo-
phakic, and 13 eyes were left phakic.

The vitreous temperature was monitored throughout vitrectomy with an MLT 1402 T-type Ultra Fast Thermocouple
Probe (Power Lab; AD Instruments, Castle Hill, Australia), which is a tissue-implantable microprobe with an ultrafast
response time of 0.005 seconds. The sensor is installed at the
tip of a 0.22-mm-diameter wire, and the wire was inserted into
the midvitreous through a 30-gauge scleral incision created by
a disposable 30-gauge needle. The thermocouple was inserted
through the sclerotomy site, 3.5 mm from the corneal limbus
and at the same clock hour midway between the medial rectus
muscle and inferior rectus muscle insertions.

An infusion cannula and two trocars were placed at the
conventional sites, and standard 23-gauge or 25-gauge vitrec-
tomy was performed. After the core vitrectomy was complet-
ed, a posterior vitreous detachment was created if one was not
already present. The ERM and internal limiting membrane in
eyes with ERM, MH, and DME, and the fibrovascular
membranes in eyes with PDR were removed, followed by
peripheral vitrectomy with a wide angle viewing system and
scleral indentation. Triamcinolone acetonide was injected into
the vitreous of all eyes to make the internal limiting membrane
more visible. Photocoagulation (PC) was performed on all eyes
with a retinal tug, retinal tear, or lattice degeneration at the
equator in cases with an ERM or MH and in all cases with DR.
Then, fluid–air exchange was performed in 26 eyes to secure
wound closure. Perfluoropropane (C₃F₈) was injected into all
19 eyes with a MH, and silicon oil was injected into seven eyes
with PDR.

### Statistical Analyses

The Kruskal-Wallis test was used to determine the significance of differences between the vitreous temperatures for the three diseases (Table 1). The Wilcoxon signed-rank test was used to determine whether there were significant differences in the changes of the temperatures between the different procedures (Table 1).

The Mann-Whitney’s U test was used to determine the significance of the differences in the temperature (Table 2).

The correlations between the number of PCs and the changes in the vitreous temperature, and the correlation
between the number of PCs and the duration of PCs (n = 22) in eyes with DR were analyzed by Spearman’s rank correlation coefficient. The correlations between the duration of membrane peeling and the change in vitreous temperature in eyes with DR (n = 18) were analyzed by Spearman’s rank correlation coefficient test.

The correlations between the change in vitreous temperature and the duration of core vitrectomy (n = 51), and the correlation between the change in vitreous temperature and the duration of peripheral vitrectomy (n = 38) were analyzed by Spearman’s rank correlation coefficient test.

### Cataract Surgery

To determine the effect of cataract surgery during vitrectomy on the vitreous temperature, we divided the cases into two
groups: vitrectomy alone and vitrectomy combined with PEA
and implantation of an intraocular lens. In 10 eyes with
combined surgery, the vitreous temperature was recorded
before and after the PEA, and the average temperatures were
compared between these two groups (Table 2). The Wilcoxon
signed-rank test was used to determine whether the differenc-
es were significant. A P < 0.05 was taken to be statistically
significant. All data are expressed as the means ± SD.

### Table 1. The Vitreous Temperature in Each Procedure

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Room Temp. (°C)</th>
<th>Body Temp. (°C)</th>
<th>Irrigating Solution (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR (n=21)</td>
<td>26.4±0.7</td>
<td>36.4±0.4</td>
<td>25.6±1.3</td>
</tr>
<tr>
<td>ERM (n=29)</td>
<td>26.1±0.7</td>
<td>36.3±0.5</td>
<td>25.3±0.9</td>
</tr>
<tr>
<td>MH (n=35)</td>
<td>26.4±0.0</td>
<td>36.3±0.4</td>
<td>25.1±0.7</td>
</tr>
<tr>
<td>Subtotal</td>
<td>26.1±1.1</td>
<td>36.3±0.4</td>
<td>25.3±1.0</td>
</tr>
</tbody>
</table>

* P < 0.05, vit alone versus combined in DR (Mann-Whitney U test).
** P < 0.01, vit alone versus combined in DR (Mann-Whitney U test).
*** P < 0.01, statistical differences between each procedure (Wilcoxon signed-rank test).

### Table 2. The Temperature Before and After Cataract Surgery

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Before Cataract Surgery, °C</th>
<th>After Cataract Surgery, °C</th>
<th>Difference in Temperature, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.5</td>
<td>30.7</td>
<td>2.8</td>
</tr>
<tr>
<td>2</td>
<td>34.0</td>
<td>29.4</td>
<td>4.6</td>
</tr>
<tr>
<td>3</td>
<td>32.3</td>
<td>29.8</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>34.4</td>
<td>31.5</td>
<td>2.9</td>
</tr>
<tr>
<td>5</td>
<td>36.4</td>
<td>32.6</td>
<td>2.2</td>
</tr>
<tr>
<td>6</td>
<td>34.4</td>
<td>32.7</td>
<td>1.7</td>
</tr>
<tr>
<td>7</td>
<td>34.2</td>
<td>32.3</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td>34.2</td>
<td>32.5</td>
<td>1.7</td>
</tr>
<tr>
<td>9</td>
<td>34.2</td>
<td>32.5</td>
<td>1.7</td>
</tr>
<tr>
<td>10</td>
<td>34.3</td>
<td>33.2</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Mean ± SD 34.0 ± 0.7 31.7 ± 1.3 2.3 ± 1.0
RESULTS

The temperature before and at the end of each procedure is presented as the mean ± SD (Table 1, Fig. 1). The room temperature was 26.4 ± 0.8°C, the body temperature at the beginning of surgery was 36.3 ± 0.4°C, and the temperature of the irrigating solution at the beginning of surgery (BSS-plus [Balanced Salt Solution-plus]; Alcon) was 25.8 ± 1.4°C. The vitreous temperature just before vitrectomy was 33.0 ± 1.3°C. During core vitrectomy, the vitreous temperature decreased by 2.3 ± 1.6°C to 30.7 ± 1.7°C. During membrane peeling, the temperature gradually increased and reached 32.9 ± 1.3°C at the end of the procedure. During peripheral vitrectomy, the temperature decreased to 29.2 ± 1.4°C, which is 3.8 ± 1.6°C lower than the temperature just before vitrectomy. These changes in vitreous temperature between consecutive procedures were significantly different (P < 0.01, Wilcoxon signed-rank test). The temperature increased to 31.5 ± 1.9°C during PC, which is 1.7 ± 2.0°C higher than that before PC.

The number of PC applications was 2153 ± 974 in eyes with DR (n = 33), 281 ± 369 in eyes with an ERM (n = 15), and 454 ± 669 in eyes with a MH (n = 13).

The differences in the vitreous temperature during each procedure such as just before vitrectomy, after core vitrectomy, after peripheral vitrectomy, before PC, and after PC among the different diseases were not significant (P > 0.05; Kruskal-Wallis test).

The changes in vitreous temperatures before and after PC in eyes with DR are shown in Figure 2. The vitreous temperature increased after PC, and there was a significant correlation between the number of PCs and the change in vitreous temperature (r = 0.578, P = 0.0011; n = 33; Spearman’s rank correlation coefficient test).

The number of PCs in eyes with DR was significantly correlated with the duration of the PC (13.9 ± 6.1 minutes; r = 0.719, P = 0.0010; n = 22; Spearman’s rank correlation coefficient test; Fig. 3A). In addition, the duration of PCs was significantly correlated with the increase of vitreous temperature (r = 0.800, P = 0.0002; n = 22; Spearman’s rank correlation coefficient test; Fig. 3B). On the other hand, the duration of membrane peeling in eyes with DR (14.9 ± 6.9 minutes) was not significantly correlated with the change in vitreous temperature (r = 0.126, P = 0.6022; n = 18; Spearman’s rank correlation coefficient test; Fig. 3C). The correlation between the duration of core vitrectomy (3.3 ± 2.1 minutes) and the change in vitreous temperature was not significant (r = 0.106, P = 0.4532; n = 51; Spearman’s rank correlation coefficient test). In addition, the correlation between the duration of peripheral vitrectomy (12.3 ± 4.0 minutes) and the change in vitreous temperature was not significant (r = 0.086, P = 0.5995; n = 38; Spearman’s rank correlation coefficient test).

![Figure 1. Vitreous temperatures at the end of each procedure during vitrectomy. The vitreous temperature decreases after cataract surgery, core vitrectomy, and peripheral vitrectomy, and increases after membrane peeling and PC. In comparison with the temperatures between subsequent procedures, the changes in the mean temperatures were significant (P < 0.01, Wilcoxon signed-rank test). The differences in the vitreous temperature during each procedure such as just before vitrectomy, after core vitrectomy, after peripheral vitrectomy, before PC, and after PC among the different diseases were not significant (P > 0.05; Kruskal-Wallis test). Closed lozenge is DR, closed square is ERM, and closed triangle is MH; core-vit means core vitrectomy; peri-vit means peripheral vitrectomy.](image1)

![Figure 2. Correlation between the number of PCs and changes in vitreous temperature. The number of PCs was significantly correlated with the changes in vitreous temperature before and after PC (n = 33, r = 0.578, P = 0.0011; Spearman’s rank correlation coefficient test).](image2)
The overall mean temperature of each procedure was significantly lower in eyes that had undergone combined PEA and vitreous surgery than in eyes with vitrectomy alone (Table 1). The temperatures before and after PC in eyes with combined cataract and vitreous surgery for DR were significantly lower than those in eyes with vitrectomy alone for DR ($P = 0.02$ and $0.0070$, respectively; Mann-Whitney’s $U$ test; Table 1). However, the number of PC in eyes undergoing combined surgery was less than that of vitrectomy alone.

The vitreous temperatures after cataract surgery in 10 patients was significantly lower than that before the surgery ($P = 0.005$; Wilcoxon signed-rank test). The mean vitreous temperature during PEA surgery alone was reduced by $2.3 \pm 1.0 ^\circ C$.

The body temperature at the beginning of surgery was not significantly correlated with the change in vitreous temperatures during core vitrectomy, membrane peeling, and endophotoocoagulation ($r = 0.117, P = 0.5087; r = -0.142, P = 0.2253$, and $r = -0.067, P = 0.6576$, respectively; Spearman’s rank correlation coefficient test).

There were no complications such as intra- and postoperative retinal tears, retinal detachments, and endophthalmitis as a result of using a thermocouple as determined by ophthalmic fundus examinations during and after the surgery.

**DISCUSSION**

Our results showed that the vitreous temperature decreased significantly during core vitrectomy, peripheral vitrectomy, and cataract surgery, and increased significantly during membrane peeling and PC. There was a significant correlation between the increase in vitreous temperature and the number of PCs and the duration of the PC.

Cataract surgery decreased the vitreous temperature significantly. The temperature before PC during the combined surgery in eyes with DR was significantly lower than that in vitrectomy alone.

Electroretinographic study during vitrectomy suggested that changes in the retinal temperature can alter retinal function temporarily. Landers et al. demonstrated that the mean midvitreous temperature was $24.9 ^\circ C$ during vitrectomy when the irrigating solution was $22.4 ^\circ C$, which was lower than that during our vitrectomy. Our data showed that the lowest temperature in the midvitreous during surgery was $29.1 \pm 1.4 ^\circ C$ just after peripheral vitrectomy when the temperature of the irrigating solution was $25.8 \pm 1.4 ^\circ C$.

The intraocular temperature may be dependent on the temperature of the irrigation fluid, the location of the thermocouple in the vitreous cavity, flow rate of the vitrectomy system, operating room temperature, and body temperature. It is also known that that the choroid can affect the temperature in the vitreous cavity. In our study, the thermocouple was inserted midway between the medial rectus muscle and inferior rectus muscle insertions, and on the opposite side of the infusion cannula in all eyes to minimize the influence of the posterior ciliary vessels. To investigate the influence of body temperature on the vitreous temperature, the correlations between the duration of core vitrectomy, membrane peeling, and endophotoocoagulation and body temperature at the beginning of surgery were analyzed; in eyes with DR ($r = 0.800, P = 0.0002; n = 22$, Spearman’s rank correlation coefficient test).

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**FIGURE 3.** Correlations between the number of PCs, the duration of PCs, and the change in vitreous temperature. Also, the correlation between the duration of membrane peeling and the change in vitreous temperature in eyes with DR. (A) Number of PCs in eyes with DR is significantly correlated with the duration of PC ($r = 0.719, P = 0.0010; n = 22$, Spearman’s rank correlation coefficient test). (B) Duration of PCs is significantly correlated with the increase in vitreous temperature ($r = 0.800, P = 0.0002; n = 22$, Spearman’s rank correlation coefficient test). (C) Duration of membrane peeling in eyes with DR was not significantly correlated with the change in vitreous temperature ($r = 0.126, P = 0.6022; n = 18$, Spearman’s rank correlation coefficient test).
however, no significant correlation was found. There is a possibility that the body temperature of each patient for each procedure might have influenced the vitreous temperature; however, the body temperature was recorded only at the beginning of surgery, and in the clinical setting during vitrectomy it might be difficult to determine the influence.

Hypothermia has been shown to protect the retina from light toxicity, elevated intracocular pressures, ischemic injury, and to decrease postoperative inflammation in animal experiments. Thus, it might be reasonable to decrease the vitreous temperature just before the use of bright lights such as during membrane peeling. Tamai et al. reported that local hypothermia can protect the retina from ischemic damage induced by high intraocular pressures. They found that temperatures of 8°C and 22°C were low enough to significantly reduce the level of glutamate, a neurotoxin, in the vitreous compared to that at 38°C. However, they also showed that retinal edema developed in the inner retinal layer at both 22°C and 38°C. They concluded that a temperature of 8°C might be suitable to reduce the damage to the retina. Our results showed that the lowest temperature during the surgery was much higher than 8°C; however, no clinical adverse effects were seen by ophthalmoscopic fundus examinations and optical coherence tomography.

The temperature increased after PC. The reasons for the increase might be a slowing of the irrigation, the temperature regulation by the choroid, and the transfer of heat from the choroid induced by the PC burn. In eyes with DR, the number of PCs was significantly correlated with the duration of PCs, and the duration of PCs was also significantly correlated with the change of vitreous temperature in the same group. These results suggest that stopping irrigation was the main cause of the increase of temperature during PC. On the other hand, the duration of membrane peeling was not significantly correlated with the temperature increase. Additional analysis showed that the correlation between the change in vitreous temperature and the duration of core vitrectomy or peripheral vitrectomy was not statistically significant. During vitrectomy on patients, there might be many factors that could affect the vitreous temperature during each procedure.

The average vitreous temperature during PEA decreased by 2.3 ± 1.0°C. Although the decreased temperature during vitrectomy combined with PEA might reduce the postoperative inflammation, other procedures during the course of vitrectomy might neutralize the lower temperatures. For example, PEA itself causes inflammation in the anterior chamber. Therefore, we cannot conclude that combined surgery is better than vitreous surgery alone from our findings.

The question arises as to what should be the optimal temperature of the irrigating solution to protect the retina. In patients with traumatic brain injury, therapeutic systemic hypothermia of 32.2°C to 33.9°C is used to minimize neurologic damage and reduce patient morbidity and mortality. However, the appropriate range of temperatures is very narrow because lower temperatures (e.g., <30°C) may cause side effects, such as electrolyte imbalances and local inhibition of platelet function and clotting factors. In addition, Bucu et al. and Honda et al. reported that extremely low temperatures of 10°C in the anterior chamber can cause a breakdown of the blood-aqueous barrier. However, in an ischemic model, Tamai et al. reported that the recovery rate of a-wave and b-wave amplitudes was significantly faster, and the glutamate level in the vitreous was significantly lower at 8°C than at 38°C. Therefore, the optimal temperature in the eye remains to be determined.

Microincision vitrectomy has recently become relatively common. However, the amount of leakage of the irrigation solution through the trocar is less than that with a 20-gauge system. During membrane peeling and PC, less leakage of the solution might lead to a more rapid increase of vitreous temperature, which might not be beneficial for the light-induced toxicity and PC-related inflammation. We need to determine the optimum temperature and suitable methods to maintain it during vitrectomy.

We have not proved that the midvitreous temperature affects the retina, and hopefully future data from animal experiments will answer this question.

In conclusion, our results showed that there were consistent changes in the midvitreous temperatures during the different procedures of vitrectomy.

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**References**


