Temperature Instability of ReNu With MoistureLoc

A New Theory to Explain the Worldwide Fusarium Keratitis Epidemic of 2004-2006

John D. Bullock, MD, MPH, MSc; Ronald E. Warwar, MD; B. Laurel Elder, PhD; William I. Northern, MS

Objective: To investigate the effect of storage temperature on the ability of contact lens solutions to inhibit growth of *Fusarium* species. A 2006 Food and Drug Administration inspection of Bausch & Lomb’s Greenville, South Carolina, manufacturing site indicated that Bausch & Lomb failed to regulate storage and transport temperatures of their products.

Methods: Six contact lens solutions were studied: ReNu with MoistureLoc, ReNu MultiPlus, COMPLETE Moistureplus, AQuify, Clear Care, and OPTI-FREE RepleniSH. Two bottles of each solution were separately stored at room temperature and 60°C for 4 weeks, serially diluted, and then tested for their ability to inhibit growth of 11 *Fusarium* isolates (7 of which were associated with the keratitis epidemic).

Results: ReNu with MoistureLoc demonstrated the greatest decline in efficacy after 60°C storage. Clear Care and ReNu MultiPlus performed the best. Regarding the keratitis epidemic isolates only, the ReNu with MoistureLoc bottle stored at room temperature allowed growth in 27 of 84 combinations vs 67 of 84 combinations with the 60°C-stored bottle.

Conclusions: When exposed to prolonged temperature elevation, ReNu with MoistureLoc loses its in vitro fungistatic activity to a much greater extent than other products. Improper temperature control of ReNu with MoistureLoc may have contributed to the *Fusarium* keratitis epidemic of 2004-2006.

Arch Ophthalmol. 2008;126(11):1493-1498

IN AUGUST 2004, BAUSCH & LOMB (Rochester, New York) introduced a new multipurpose soft contact lens solution, ReNu with MoistureLoc, containing the bis-biguanide antimicrobial agent alexidine, not found in other contact lens solutions.1 In early March 2006, the first US reports of ReNu-related *Fusarium* keratitis were reported to both the Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention (CDC) from Newark, New Jersey, and (by 2 of us, J.D.B. and R.E.W.) Dayton, Ohio. A total of 154 confirmed cases were identified in the United States and the use of ReNu with MoistureLoc was significantly associated with having *Fusarium* keratitis (adjusted odds ratio, 22.3).1

Numerous researchers have since attempted to explain the etiology of this epidemic. Bausch & Lomb investigators acknowledged that all original cases appear to be related to ReNu with MoistureLoc produced in their Greenville, South Carolina, plant.2 The CDC found no fungal contamination of unopened bottles produced by that plant (including bottles with the same lot numbers as those that were used by affected patients) and noted multilocus genotyping of clinical isolates from affected patients, essentially excluding the possibility of a single-point source contamination of the solution itself.1 They concluded that this epidemic was due to failure of ReNu with MoistureLoc to disinfect adequately after point-of-use contamination rather than from intrinsic contamination with *Fusarium*.1,3 Factors hypothesized to have contributed to this epidemic include direct uptake of alexidine by contact lenses,4 reduced antimicrobial activity of evaporated ReNu with MoistureLoc,5 enhanced growth of *Fusarium* on ReNu with MoistureLoc biofilms on contact lens cases,6,7 direct penetration of *Fusarium* into soft contact lenses,8,9 and patient noncompliance.2 However, none of these factors, either alone or in combination, would explain why only the ReNu with MoistureLoc produced in South Carolina (as opposed to the other manufacturing sites in Italy, China, and India) had been implicated.

While Bausch & Lomb researchers Levy et al stated that “product and plant inspections had failed to show any remarkable anomalies,”2(p260) the following should be noted. From March 22 to May 13, 2006, the FDA inspected Bausch & Lomb’s Greenville facility, which had manufactured the suspect ReNu with MoistureLoc. They released their findings in FDA Form 483 in

Author Affiliations:
Departments of Ophthalmology (Drs Bullock and Warwar), Community Health (Dr Bullock), Mathematics and Statistics (Dr Bullock), and Pathology (Dr Elder), Wright State University Boonshoft School of Medicine, and CompuNet Clinical Laboratories (Mr Northern), Dayton, Ohio.

©2008 American Medical Association. All rights reserved.

which Bausch & Lomb was cited for inadequacies in temperature control in the production, storage, and transport of their products.10,11 We have no way of knowing if Bausch & Lomb monitored the temperature of the storage warehouses and/or transporting vehicles at any of the other manufacturing sites. Because of these facts, and to investigate further the cause of this worldwide epidemic,12,13 we undertook a study to determine the effects of elevated temperature on the antifungal properties of ReNu with MoistureLoc and other contact lens solutions.

### Methods

The following 6 multipurpose solutions (with their antimicrobial agents) were used: ReNu with MoistureLoc (0.00045% alexidine) and ReNu MultiPlus (0.0001% polyaminopropyl biguanide) (Bausch & Lomb); COMPLETE Moistureplus (0.0001% polyhexamethylene biguanide [Advanced Medical Optics, Santa Ana, California]); AQuify (0.0001% polyhexanide) and Clear Care (3% hydrogen peroxide) (CIBA Vision, Duluth, Georgia); and OPTI-FREE RepleniSH (0.0005% myristamidopropyl dimethylamine, 0.001% polyquaternium-1 [Alcon Laboratories, Ft Worth, Texas]). All bottles were procured in the Dayton area. The Bausch & Lomb products were labeled “Made in USA.”

Eleven Fusarium isolates were obtained from the following institutions: CDC, Atlanta, Georgia (7 isolates), Stanford University, Palo Alto, California (2 isolates), and CompuNet Clinical Laboratories, Dayton (2 isolates). Isolates from the CDC represented 3 different species complexes and multiple genotypes from the Fusarium epidemic.1 These were the only isolates received from the CDC; their basis for selection is unknown. Isolates from Stanford and CompuNet were not involved in the epidemic (Table 1).

### PILOT STUDY

A pilot study was undertaken using 2 Fusarium isolates to determine the effects of elevated temperature on the antifungal properties of ReNu with MoistureLoc and other contact lens solutions. One sealed, unopened, unexpired bottle of each of the 6 contact lens solutions was maintained at room temperature (23°C [73.4°F], as monitored by a standard indoor thermostat in a strictly temperature-controlled laboratory), and a second sealed, unopened, unexpired bottle was maintained in a water bath at 60°C (140°F) for 4 weeks and then allowed to return to room temperature for 1 day. A 10-mL aliquot was removed from the room temperature–stored bottle and boiled in a glass tube for 10 minutes, then allowed to return to room temperature. Serial dilutions of the 3 samples (room temperature, 60°C, and boiled) of each contact lens solution were then made in sterile plastic tubes using Sabouraud dextrose broth (SDB). Because the 2 Dayton keratitis isolates had been previously sent to the CDC at their request, 2 different clinical isolates of Fusarium from CompuNet (CCL1 and CCL2), not associated with the epidemic, were used. We do not know the exact clinical sources of these isolates; both specimens were stored in the laboratory either by freezing at −70°C (CCL1) or by subculturing (CCL2). Each isolate was plated on Sabouraud dextrose agar (SDA) and incubated for approximately 7 days when growth and sporulation were present. Testing was performed by adapting the recommendations of the National Committee for Clinical Laboratory Standards (NCCLS) on susceptibility testing of filamentous fungi.16 Suspensions of each isolate were prepared in SDB to a McFarland 0.5 standard density equivalent, then diluted 1:50 in SDB. A 0.5-mL aliquot of the 1:50 dilution of each Fusarium suspension was added to 0.5 mL of each serial dilution of the contact lens solutions (subjected to the temperatures) in sterile plastic tubes for final dilutions of 1:2, 1:4, 1:8, and 1:16. A single sample for each dilution was performed. The tubes were incubated at 35°C for 1 week and then observed for fungal growth by visual inspection. The observer was blinded to the contact lens solution but not dilution. A growth control (0.5 mL of 1:30 diluted Fusarium suspension and 0.5 mL of SDB) was performed for both isolates.

### EXTENDED STUDY

Based on the results of the pilot study, the following 4 contact lens solutions (using different bottles from the pilot study) were used in the extended study: ReNu with MoistureLoc, ReNu MultiPlus, Clear Care, and OPTI-FREE RepleniSH. One sealed, unopened bottle of each of the 4 contact lens solutions was maintained at room temperature as before and a second sealed, unopened bottle was maintained in the water bath at 60°C for 4 weeks. With the exception of 1 ReNu with MoistureLoc bottle, all of the other bottles were unexpired and each of the 2 bottles for the other (not ReNu with MoistureLoc) product brands had the same lot numbers. Because of limited availability owing to the worldwide recall, the 2 ReNu with MoistureLoc bottles had different lot numbers and expiration dates. The bottle stored at room temperature had an expiration date approximately 6 weeks prior to the inoculation of the samples and the bottle stored at 60°C had an expiration date approximately 6 weeks after the inoculation of the samples. Thus, the ReNu with MoistureLoc bottle stored at room temperature was slightly past its expiration date but the ReNu with MoistureLoc bottle stored at 60°C was within its expiration date at the time of inoculation of the samples of contact lens solutions. For all solutions, the bottles stored at 60°C were then kept at room temperature for approximately 2 weeks prior to the next phase of the experiment. The bottles stored at room temperature were kept at room temperature for the entire 6-week period. Serial dilutions of the 2 samples (room temperature and 60°C) of each contact lens solution were then made in sterile 48-well tissue culture plates using Hanks balanced salt solution. Fusarium isolates were plated on SDA and incubated for approximately 7 days when growth and sporulation were present. Testing was again performed by adapting the recommendations of the NCCLS.16 Suspensions of each isolate were prepared in sterile saline to a McFarland 0.5 standard density equivalent. A 1:50 dilution of the suspension was made in both SDB and RPMI-
RESULTS

PILOT STUDY

With regard to *Fusarium* isolate CCL2, no contact lens solution allowed growth at 1:2 or 1:4 dilutions under any temperature conditions, and only 1 solution (AQuify) demonstrated a 1-dilution decline in inhibition of CCL2 growth after incubation at 60°C or boiling (data not shown). Isolate CCL1 was more resistant to inhibition by the contact lens solutions (Table 4). After 60°C storage, OPTI-FREE RepleniSH and ReNu with MoistureLoc were the only products to allow growth of CCL1 at all dilutions, and ReNu with MoistureLoc was the only product that demonstrated a 2-dilution (≥4-fold concentration) decline in efficacy relative to room temperature. After boiling, OPTI-FREE RepleniSH was the only product to allow growth of CCL1 at all dilutions and was the only product to show a decline in efficacy relative to room temperature. The solutions that were the most efficacious in inhibiting *Fusarium* growth were Clear Care and ReNu MultiPlus, with neither allowing growth of either isolate after 60°C storage. Fungal growth was observed in control tubes for both isolates.

EXTENDED STUDY

Results are summarized in Tables 5, 6, and 7. A total of 336 combinations were tested for each of the 4 contact lens solutions: duplicate combinations for each of the 7 CDC and 2 Stanford isolates and quintuplicate combinations for each of the 2 CompuNet isolates, all performed in 2 dif-
In RPMI, OPTI-FREE RepleniSH completely inhibited growth of all 11 isolates after storage at room temperature and 10 of 11 isolates after 60°C storage. In SDB, OPTI-FREE RepleniSH allowed growth of 6 of the 11 isolates after room-temperature storage; of those 6 isolates, all 6 were able to grow at lower dilutions than with the room-temperature–stored ReNu with MoistureLoc stored at room temperature.

ReNu with MoistureLoc was less successful at inhibiting fungal growth than the other 3 products and again demonstrated the greatest decline in efficacy after 60°C storage (P < .01) (Table 7 legend). In RPMI, ReNu with MoistureLoc completely inhibited growth of 4 isolates at both room temperature and 60°C but allowed growth of the other 7 isolates at both temperatures. Of those 7 isolates that grew in RPMI after room temperature storage, 6 were able to grow at lower dilutions after 60°C storage. In SDB, ReNu with MoistureLoc (both room temperature and 60°C) completely inhibited growth of 3 isolates but allowed growth of 7 of the other 8 isolates after room temperature storage and 8 of 8 after 60°C storage. Of those 8 isolates that grew in SDB after 60°C storage, 7 were able to grow at lower dilutions than with the room temperature–stored ReNu with MoistureLoc. With regard to the 7 CDC epidemic isolates only, 60°C-stored ReNu with MoistureLoc allowed growth in 67 of 84 combinations vs growth in only 27 of 84 combinations with room temperature–stored ReNu with MoistureLoc. Fungal growth was observed in control wells for all isolates.

**COMMENT**

The Arrhenius equation \( k = A e^{−A/T_D} \) is a mathematical expression of the dependence of the rate of a chemical reaction, \( k \), on temperature, \( T \), in Kelvins (K). \(^{17}\) (A in-

**Table 5. Extended Study: Contact Lens Solution Inhibition of* Fusarium* Growth After Storage at 23°C or 60°C in RPMI Culture Medium**

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Inhibitory Titera</th>
<th>Inhibitory Titera</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23°C 60°C</td>
<td>23°C 60°C</td>
</tr>
<tr>
<td>CDC B6902</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CDC B6947</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CDC B6980</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CDC B6984</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CDC B7029</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CDC B7090</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>Stanford 1</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>Stanford 2</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CCL1</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CCL2</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
</tbody>
</table>

*Abbreviations: RPMI, RPMI-1640 medium with glutamine; \( \Delta \) represents the increase in inhibitory titer required to inhibit fungal growth between different media (RPMI and SDB), at 23°C and 60°C.

**Table 6. Extended Study: Contact Lens Solution Inhibition of* Fusarium* Growth After Storage at 23°C or 60°C in SDB Culture Medium**

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Inhibitory Titera</th>
<th>Inhibitory Titera</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23°C 60°C</td>
<td>23°C 60°C</td>
</tr>
<tr>
<td>CDC B6902</td>
<td>1.4 1.4</td>
<td>1.4 1.4</td>
</tr>
<tr>
<td>CDC B6947</td>
<td>1.2 &lt;1.2</td>
<td>1.2 &lt;1.2</td>
</tr>
<tr>
<td>CDC B6980</td>
<td>1.4 1.2</td>
<td>1.4 1.2</td>
</tr>
<tr>
<td>CDC B6984</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CDC B7029</td>
<td>1.2 &lt;1.2</td>
<td>1.2 &lt;1.2</td>
</tr>
<tr>
<td>CDC B7090</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>Stanford 1</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>Stanford 2</td>
<td>≥1.8 ≥1.8</td>
<td>≥1.8 ≥1.8</td>
</tr>
<tr>
<td>CCL1</td>
<td>&lt;1.2 &lt;1.2</td>
<td>1.4 &lt;1.2</td>
</tr>
<tr>
<td>CCL2</td>
<td>≥1.8 ≥1.8</td>
<td>1.4 ≥1.8</td>
</tr>
</tbody>
</table>

*Abbreviations: SDB, Sabouraud dextrose broth; \( \Delta \) represents the increase in inhibitory titer required to inhibit fungal growth between solutions stored at 23°C and 60°C.

**Table 7. Increase in *Fusarium* Inhibitory Titer of Contact Lens Solutions After Storage at Room Temperature vs 60°C**

<table>
<thead>
<tr>
<th>Contact Lens Solution</th>
<th>Increase in Inhibitory Titera</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>ReNu With MoistureLoc</td>
<td>9</td>
</tr>
<tr>
<td>OPTI-FREE RepleniSH</td>
<td>18</td>
</tr>
<tr>
<td>ReNu MultiPlus</td>
<td>22</td>
</tr>
<tr>
<td>Clear Care</td>
<td>22</td>
</tr>
</tbody>
</table>

*Abbreviations: 0, no change in inhibitory titer.

A inhibitory titer represents the highest dilution of the contact lens solution tested (1:2, 1:4, or 1:8) that inhibited fungal growth in both duplicate or in at least 3 of 5 quintuplicate samples tested after storage at room temperature (23°C [73.4°F]) or after storage in a 60°C (140°F) water bath for 4 weeks. Inhibitory titer and increase in inhibitory titer are defined and explained in detail in Table 2 and Table 3. ReNu MultiPlus (Bausch & Lomb) and Clear Care (OIBA Vision, Duluth, Georgia) inhibited fungal growth completely in all combinations of isolates, dilutions, media, and temperatures tested (data not shown). *Fusarium* isolates are described in detail in Table 1. Testing was performed in duplicate for each medium and temperature tested for the CDC and Stanford isolates and in quintuplicate for the CCL isolates.
cludes factors like the frequency of molecular collision and orientation; $E_a$, minimum activation energy for a chemical reaction to occur; $e$, Euler constant, having a value of 2.71828; and $R$, the constant in the equation, \( pV=nRT \). This rate will approximately double for every 10 K (or 10°C) rise in temperature. This equation is the basis for one of the 1997 FDA guidelines concerning contact lens care products, in which they noted:

- generally every 10°C increase for tested temperature will enhance the expiration date by a factor of two compared to the normal storage temperature.\(^{10p160}\)

Thus, the approximate theoretical relative fractional shelf-life equals $1/2^{pV/R}$, where $\Delta t$ is the storage temperature elevation, higher than room temperature, in degrees Celsius. For example, if a product were stored at 53°C (30°C >room temperature of 23°C), the theoretical shelf-life would be: $1/2^{50/10}=1/2^5=1/32$ of the shelf-life if stored at room temperature. A thermally induced chemical alteration resulting in a decrease in antimicrobial concentration may be critical, as Cohen\(^{19}\) noted that a 2-fold reduction in antimicrobial concentration in contact lens solutions was associated with a 10-fold decrease in reduction of fungal contamination.

Leung et al\(^{20}\) studied the effect of storage temperature and time on the efficacy of 4 multipurpose solutions, including ReNu MultiPlus (but not ReNu with MoistureLoc, as the product had not yet been released). They noted that the antimicrobial activity of ReNu MultiPlus toward *Pseudomonas aeruginosa* dropped lower than FDA guidelines when stored at 30°C (86°F) for 2 months. They also noted decreased activity of ReNu MultiPlus and COMPLETE Multi-Purpose (Allergan, Irvine, California) toward *P aeruginosa* when the solutions were stored at 4°C (39°F). They concluded that multipurpose solution stability may be adversely affected by higher, lower, or fluctuating temperatures.

Previous investigators have measured temperature rises within enclosed vehicles. King et al\(^{21}\) found that with an ambient temperature of 36.8°C (98.2°F), the temperature within vehicles reached up to 67°C (153°F) within 15 minutes. McLaren et al\(^{22}\) found up to a 27°C (49°F) temperature rise within enclosed vehicles relative to ambient temperatures of 22°C to 36°C (72°F-96°F) after 60 minutes. Morgan et al,\(^{23}\) while studying the impact of temperature on the stability of latanoprost (Xalatan; Pfizer Ophthalmics, Pharmacia, and Upjohn, Kalamazoo, Michigan), noted that in the southern United States during summer months, temperatures within enclosed spaces can reach 75°C (167°F). Non-temperature controlled warehouses can easily reach 40°C (104°F) in summer months.\(^{24}\)

Maximum temperatures in the Greenville area in June 2005 (the month prior to the first reports of ReNu with MoistureLoc–associated keratitis\(^{12}\)) were typically higher than 32°C (90°F).\(^{25}\) Thus, the logistics of storing, transporting, and delivering liquid pharmaceuticals and contact lens solutions in a temperature-controlled environment is an extremely important issue.

The 5 other multipurpose solutions tested with ReNu with MoistureLoc in the pilot study were selected because they were the more commonly used products at the time of this study. Based on the results of the pilot study, we chose to investigate further the products that demonstrated the most (Clear Care) and least (OPTI-FREE RepleniSH) fungistatic efficacy, including the other product manufactured by Bausch & Lomb in Greenville (ReNu MultiPlus). The results of the extended study verified and confirmed the results of the pilot study. A water bath in our laboratory is maintained at 60°C for other purposes. This temperature was used to simulate conditions to which some of the manufacturer’s bottles may have been exposed during storage, transport, or after purchase. Future studies using multiple temperatures with fungal as well as bacterial organisms may be beneficial. Interestingly, in our pilot study, boiled ReNu with MoistureLoc inhibited *Fusarium* growth of 2 isolates (CCL1 and CCL2) equally as well as room temperature–stored ReNu with MoistureLoc. This suggests that alexidine inactivation is both time and temperature dependent. While Bausch & Lomb investigators Levy et al\(^{2}\) report performing “extended storage studies” as well as “elevated temperature studies, including impact on biocidal efficacy versus *F. [Fusarium] solani,*” of ReNu with MoistureLoc, they neglected to report the results of those specific studies.

The *Fusarium* species tested in our extended study included 7 epidemic isolates from the CDC and 4 nonocular isolates from 2 different institutions. The majority of the isolates were from the epidemic, which may have biased the results toward isolates demonstrating resistance to ReNu with MoistureLoc. Furthermore, our results represent in vitro findings; fungal growth in a nutrient broth may be different from growth in a contact lens case.

The precise temperature, duration of exposure to elevated temperature, and extent of temperature fluctuation that may diminish the antimicrobial activity of a particular contact lens solution is not known, and thus, additional studies may be warranted. However, our findings, coupled with the FDA reports of Bausch & Lomb’s failure to regulate the storage and transport temperatures of the products manufactured in their Greenville plant, may be significant. Previously cited studies have suggested that ReNu with MoistureLoc has characteristics making it vulnerable to *Fusarium* infection.\(^{1,2}\) Our study demonstrated loss of fungistatic activity of ReNu with MoistureLoc on 4-week exposure to 60°C (140°F). These factors, together with the FDA findings of temperature control issues in and beyond the Greenville plant, may have potentiated a set of circumstances that led to the epidemic of ReNu with MoistureLoc–related *Fusarium* keratitis. Knowledge of the potential loss of antimicrobial activity of contact lens solutions and other pharmaceutical products when exposed to higher temperatures and the risk of such exposure when storing and transporting those products may help prevent such epidemics in the future.

Submitted for Publication: April 9, 2008; final revision received July 8, 2008; accepted July 11, 2008.

Correspondence: John D. Bullock, MD, MPH, MSc, Center for Global Health Systems, Management, and Policy, Wright State University Boonshoft School of Medicine, 3123 Research Blvd, 200, Dayton, OH 45420-4006 (johnnbullock@aol.com).

Author Contributions: Dr Bullock had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Financial Disclosure: Dr Bullock has served as a consultant for three different law firms concerning the Fusarium keratitis epidemic. The compensation was paid to the Wright State University Foundation and not to Dr Bullock. No outside funding from any source was provided for this study. Any and all costs associated with this research study were paid for by the authors personally or by Compu-Net Clinical Laboratories.

Previous Presentation: This material was presented at the American Ophthalmological Society Annual Meeting: May 17, 2008; Colorado Springs, Colorado, and subsequently will be published in Transactions of the American Ophthalmological Society.

Additional Contributions: Mary E. Brandt, PhD, of the Centers for Disease Control and Prevention, Atlanta, Georgia, and Diane Getsinger, CLS, MT(ASCP), of Stanford University Medical Center, Palo Alto, California, provided Fusarium isolates for this study.

REFERENCES


