cium levels. Calcium ions antagonize this effect. Imidazole exerts a hypocalcemic effect similar to thyrocacitomin. Since A23187 is known to transfer calcium across cell membranes, it is attractive to speculate that the inhibition of the ocular action of A23187 by imidazole also involves calcium ion.

In contrast, the elevation of intraocular pressure induced by topical application of the ionophore X537A is not blocked by parenteral pretreatment with imidazole. Although A23187 is relatively specific for divalent cations, X537A can transport monovalent cations and catecholamines. The stimulation of catecholamine release from cat adrenals by A23187 is abolished by perfusion with calcium-free solution, whereas the stimulation in this system produced by X537A is only reduced.

Although both ionophores can stimulate through a calcium-dependent mechanism, they differ in that other factors besides calcium may be important in the X537A effect.

The level of calcium in aqueous humor from eyes treated with either ionophore or from eyes of animals treated with imidazole is no different from that of controls (unpublished observations). Thus the mechanisms for the ionophore-induced elevation of intraocular pressure and for the effect of pretreatment with imidazole on this rise remain unknown. Possibly, intracellular distribution of calcium ion may be altered in these circumstances. Nevertheless, it is clear that imidazole blocks a variety of stimuli that produce ocular hypertension, and this observation is a clue to the elucidation of the factors which control aqueous humor dynamics.

A generous supply of ionophore A23187 was provided by Dr. Robert L. Hamill, Lilly Research Laboratories, Eli Lilly & Co., Indianapolis, Ind., and of ionophore X537A by Dr. W. E. Scott, Hoffman-LaRoche, Inc., Nutley, N. J.

From the Department of Ophthalmology, Mount Sinai School of Medicine of The City University of New York, New York, N. Y. This investigation was supported in part by research grants EY-01661 and EY-01867 from the National Eye Institute, Bethesda, Md., and an unrestricted grant from Research to Prevent Blindness, Inc., New York, N. Y. Submitted for publication March 30, 1977.

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Key words: ionophores A23187 and X537A, imidazole, intraocular pressure.

References


Evaluation of an electronic corneal pachometer. PERRY S. BINDER, JOHN A. KOHLER, AND DALE A. RORABAUGH.

Sixteen patients who had never worn contact lenses underwent measurement of their central corneal thicknesses with the standard corneal pachometer and a new electronic corneal pachometer. Both instruments were able to produce repeatable and accurate results, although the overall measurements obtained were thicker with the electronic pachometer. The advantage of the electronic pachometer over the standard pachometer is that one is able to easily measure areas other than the central cornea with repeatable accuracy.

With the addition of a microcomputer and printout system, large populations can be studied, and changes in corneal thickness can be recorded on a day-to-day or hour-to-hour basis.

In recent years, the corneal pachometer has gained wide acceptance for measuring corneal thickness. The pachometer is useful for evaluating
corneal swelling which can occur after intraocular surgery,\textsuperscript{2,3} for the evaluation of postoperative keratoplasty cases,\textsuperscript{4} and for the evaluation of the cornea during contact lens wear.\textsuperscript{5,6} An electronic corneal pachometer has been devised to improve the accuracy of measurement.\textsuperscript{7,8} The purpose of this project was to compare the accuracy of the new electronic pachometer with the presently accepted Haag-Streit modification of the Mishima pachometer.

\textbf{Materials and methods.} Thirteen women and three men whose ages ranged from 18 to 27 years were studied. Fifteen were white and one was black, and none had ever worn contact lenses. All patients studied had no previous history of ocular disease. After a brief clinical history had been obtained, each patient underwent determination of the corneal thickness in both eyes. First, the right cornea was measured with the standard Haag-Streit corneal pachometer (Haag-Streit AG, Berne, Switzerland), which was mounted on a Haag-Streit 900 slit lamp.\textsuperscript{1,3,5} Fixation lights were not used, but care was taken to assure that the light beam was perpendicular to the central corneal surface. The end point of each measurement was the apposition of Descemet's membrane of one split image with Bowman's membrane of the other split image.

Five separate readings were taken for each eye, and no corrections were made for corneal curvature. Then the left corneas were examined in a similar fashion. All readings with this technique were performed by one of us (P.S.B.).

The electronic corneal pachometer (Diagnostic Concepts Inc., San Diego, Calif.) was next used to measure the corneal thickness (Fig. 1). This machine uses nine fixation lights (Fig. 2). The central light makes an angle of 35° with the viewing ocular, and each of four fixation lights lies 5° from the central light nasally and temporally. With the central fixation light in position, the slit beam strikes the central cornea approximately 20° off the perpendicular. This reading was recorded as an oblique corneal thickness measurement. Use of the fixation light 15° to the right of center causes the slit beam to strike the cornea approximately 5° off the perpendicular and tends to produce readings which are thinner than those obtained with a more oblique light beam. This reading was recorded as direct corneal thickness measurement.

The fixation device contains 11 fixation light-emitting diodes, with nine in the horizontal plane and two in the vertical plane (Fig. 2). A measurement potentiometer which is connected to a rotating glass plate is used in conjunction with the
slit-lamp biomicroscope. The potentiometer is adjusted via a control arm to convert the mechanical position of the glass plate into an electrical signal proportional to the corneal thickness. The electrical output of the measurement potentiometer is routed to a high input impedance amplifier located in the electronics enclosure (Fig. 1). The isolation amplifier drives a 3½ digit analog digital converter. The system element converts the electrical signal into a corresponding digital equivalent.

The electronic pachometer was calibrated before and after the experiment. The calibration technique is to first adjust the mechanical scale on the potentiometer for both 0 and full scale and record the corresponding digital values. These values can then be used to compute correction factors for each type of measurement error. A different correction factor can be obtained for different observers; however, only one correction factor was used in this experiment. The major source of error occurs with the end-point alignment of the beam, but the two vertical lights assisted in improving the alignment for central corneal readings.1

Each patient underwent an oblique measurement and a direct measurement in the same eye with the electronic pachometer. The end point of measurement was the same as that for the standard pachometer. One of the authors experienced in the use of the electronic pachometer (J. A. K.) performed only oblique readings, whereas direct and oblique readings were performed by one of us (P. S. B.) who had never previously used the electronic pachometer. Five readings were recorded with each technique, and the same techniques were used on right and left eyes. The mean and standard deviation of each set of five readings were recorded. The Student t test was utilized for comparison of data.

Results. The average corneal thickness obtained with the standard pachometer was 0.490 ± 0.015 mm. S.D. There was no significant difference between readings taken in right and left eyes. The average corneal thickness recorded with the electronic pachometer from oblique measurement was 0.644 ± 0.013 mm S.D. and from direct measurement was 0.607 ± 0.018 mm. S.D. There was no difference between the measurement of right and left eyes with the oblique or direct technique by either of the two investigators; however, the readings obtained with the standard pachometer was significantly thinner (p < 0.01) than those readings obtained with the electronic pachometer. In addition, the readings taken by the same observer with direct measurement and oblique measurement with the electronic pachometer were significantly different (p < 0.01).

Discussion. The electronic pachometer has been utilized to measure the corneal thickness in areas other than the central cornea2 and has been used to measure qualitative increases in central corneal thickness under various experimental conditions.3 When 10 measurements are recorded at the same central corneal position, the accuracy of reproducibility has been reported to be ± 0.0054 mm,4 and the mean value for central corneal thickness in normal eye with the electronic pachometer has been reported to be 0.506 ± 0.04 mm. S.D.5

Table I. Thickness of the human cornea6

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Corneal thickness S.D. ± (mm.)</th>
<th>Pachometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>von Bahr.</td>
<td>1948</td>
<td>0.565 ± 0.035</td>
<td>von Bahr</td>
</tr>
<tr>
<td>Maurice and Giardini</td>
<td>1951</td>
<td>0.507 ± 0.028</td>
<td>Maurice-</td>
</tr>
<tr>
<td>Lavergne and Kelecom</td>
<td>1962</td>
<td>0.51 ± 0.04</td>
<td>Goldman</td>
</tr>
<tr>
<td>Donaldson</td>
<td>1965</td>
<td>0.522 ± 0.041</td>
<td>Donaldson</td>
</tr>
<tr>
<td>Mishima and Hedbys</td>
<td>1968</td>
<td>0.518 ± 0.02</td>
<td>Haag-Streit</td>
</tr>
<tr>
<td>Mandell and Polse</td>
<td>1969</td>
<td>0.506 ± 0.04</td>
<td>Electronic</td>
</tr>
<tr>
<td>Farris</td>
<td>1971</td>
<td>0.510 ± 0.03</td>
<td>Maurice-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Giardini</td>
</tr>
<tr>
<td>Binder</td>
<td>1976</td>
<td>0.49 ± 0.015</td>
<td>Haag-Streit</td>
</tr>
</tbody>
</table>

*Modified from Mishima and Hedbys.6

Measurements of central corneal thickness obtained with the standard pachometer have previously been determined to be somewhat thicker than those with the electronic pachometer (Table I). In the present experiment, the measurement of central corneal thickness with the standard pachometer is even less than that previously reported in the literature, and this may be due in part to the elimination of the epithelium in the measurement of the thickness. However, the accuracy of the measurement appears to be well within the range of that previously reported.

Measurement of the central corneal thickness with the electronic pachometer direct technique in 16 patients was significantly thicker than that reported by Mandell and Polse,5 but the standard deviation was comparable. The accuracy of measurement by the same observer using the standard pachometer and the electronic pachometer appear to be equivalent; however, the absolute value of corneal thickness obtained is significantly thicker with the electronic pachometer. This difference may be due to the technique of measurement which uses a light beam that strikes the cornea at an angle of 5°, thereby producing thicker readings. Although the two observers were able to obtain repeatedly accurate measurements, there was a significant difference between their two measurements of central corneal thickness with the oblique technique (p < 0.01).
In this experiment, the electronic pachometer when used by an untrained operator was no more accurate than the standard corneal pachometer when used by someone familiar with its use. Although the electronic pachometer is able to provide corneal thickness measurements to four decimal places, the ultimate accuracy of the machine depends on the end point alignment of the corneal parallelpipeds. This end point was difficult to repeat when multiple measurements were made on the same cornea, but the accuracy of the measurement was no different than that obtained with the standard pachometer.

The electronic pachometer is easy to use and gives repeatable results with a high degree of accuracy under conditions in which the observer has not been specifically trained in its use. One advantage of the electronic pachometer is the ability to measure different areas of the cornea in a repeatable fashion because of the 5° separation of the fixation lights. With the addition of a microcomputer (Diagnostic Concepts, Inc.) which can calculate the mean and standard deviation for a series of readings, the electronic pachometer would be very useful for evaluating corneal thickness under various experimental conditions such as the continuous wear of hydrophilic lenses. The rapidity with which these measurements can be made and recorded would be advantageous when large populations are to be studied. The standard pachometer in trained hands is an accurate instrument and compares favorably with the electronic pachometer for central corneal thickness readings, but it is more difficult to use when measuring peripheral corneal thicknesses.

From the Section of Ophthalmology, Veterans Administration Hospital, San Diego, California. Supported by the Medical Research Service of the Veterans Administration. Submitted for publication March 14, 1977. Reprint requests: Perry S. Binder, M.D., 3350 La Jolla Village Drive (112G), San Diego, Calif. 92161.

Key words: corneal pachometry, corneal thickness, electronic pachometry.

REFERENCES


Basophils in vernal conjunctivitis in humans: an electron microscopic study.

H. BARRY COLLIN* AND MATHEA R. AL-LANSMITH.

The histopathological changes of vernal conjunctivitis comprise stromal infiltration by lymphocytes, plasma cells, and neutrophile, eosinophilic, and basophilic leukocytes and epithelial invasion by mast cells and eosinophils. Blood vessels show swelling and death of endothelial cells and increased permeability with associated extravasation of erythrocytes and fibrin. The presence of basophils in ocular tissue has not been reported previously, and their occurrence in conjunction with the other pathological changes enables vernal conjunctivitis to be compared with, and classified as a manifestation of, delayed-type hypersensitivity of the cutaneous basophil type. Thus the mechanism is probably a mixture of both delayed and immediate immunological responses.

The clinical characteristics of vernal conjunctivitis have been extensively described, and when the patient presents with a typical picture, diagnosis is seldom difficult. However, although "the pathological changes in vernal conjunctivitis have been fully investigated," there have been only two electron microscopic studies of this condition. In view of the absence of an adequate theory to fully describe the mechanism of vernal conjunctivitis, which is considered to be allergic, atopic, or probably a mixture of delayed and immediate immunological responses, this investigation was begun.

Methods. Biopsy material consisted of conjunctival tissue from the upper tarsus of two patients and from the upper and lower tarsal regions of a third patient, all of whom had typical palpebral vernal conjunctivitis (Fig. 1), and from the upper tarsal region of one patient in which the conjunc-