Electronic applanation tonometry in corneal edema and keratoplasty

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The effect of corneal edema and the effect of penetrating keratoplasty upon the accuracy of electronic applanation tonometry were studied in rabbits. Pressure readings made directly from cannulas in the anterior chamber correlated well with those made by electronic applanation tonometry both in severe corneal edema and 24 hours after penetrating keratoplasty. The advantages of electronic applanation tonometry in patients with corneal disease are discussed.

Key words: Tonometry, corneal edema, electronic applanation tonometer, MacKay Marg tonometer, penetrating keratoplasty, corneal curvature, corneal thickness, artificial change of intraocular pressure, anterior chamber cannulation, rabbits.

Many patients have corneal diseases which make it difficult to measure intraocular tension by either the Goldmann applanation or the Schiötz tonometers. Applanation with the Goldmann instrument requires an area of cornea greater than 3 mm. in diameter with a smooth, regular curvature; moreover the presence of corneal sutures, which pool fluorescein, hinders applanation tonometry. The footplate of the Schiötz tonometer is designed for corneas with a standard curvature. Attempts to use this instrument on corneas whose curvature has been markedly altered can only be misleading. The desire to find a method of accurately measuring intraocular tensions in patients after keratoplasty led us to an evaluation of the MacKay-Marg electronic applanation tonometer.1-3 The fact that this instrument has an applanating surface of only 1.5 mm. and does not require fluorescein provides obvious advantages. Trials in our clinic have shown that readings taken upon normal human anesthetized corneas with the MacKay-Marg instrument correlate well with Goldmann applanation readings.4 The present study was undertaken to determine whether corneal edema or the corneal distortion and flattening produced by keratoplasty affect the accuracy of the readings.

Materials and methods

Experiment 1. Effect of corneal edema upon intraocular pressure measurements. New Zealand white rabbits weighing 2.5 to 3.5 kilograms were sedated with chlorpromazine. One cornea of each rabbit was anesthetized with topical 0.5 per cent chlorpromazine. The experiment was performed in the following manner:

1. The rabbit was placed in a head holder and the right eye was anesthetized with 0.5 per cent chlorpromazine.
2. A small incision was made in the cornea and a cannula was inserted into the anterior chamber.
3. A pressure reading was taken with the MacKay-Marg instrument.
4. The cannula was removed and the cornea allowed to return to normal.
5. The process was repeated two more times.

The results of this experiment were then compared with the Goldmann method.
Fig. 1. Correlation of pressure measurements made by direct cannulation of the anterior chamber with those made by applanation with the MacKay-Marg tonometer on normal and edematous corneas. Normal eyes are represented in the upper graph and eyes with edematous corneas in the lower. The slope is 0.96 for the normal eyes and 0.93 for those with edematous corneas. The slopes were calculated with the restriction that the lines must go through the origin by the formula: slope = \( \frac{\sum X Y}{\sum X^2} \). Such a restriction makes it more difficult to obtain a high degree of correlation. The correlation coefficient was 0.97 for the normal eyes and 0.98 for those with edematous corneas and thus the high degree of correlation obtained would seem to indicate that the restriction is valid. The slope was also calculated without this restriction and the intercept thus obtained was no significantly different from zero.
proparacaine hydrochloride, and five to ten applications were made to this cornea with the Frigotonic 2 mm. cryoprobe at -60° C.\(^6\)

Twenty-four hours later the treated corneas had become markedly edematous. The corneal thickness was measured in both the treated and untreated eye of each rabbit with a Haag-Streit pachometer as modified by Mishima and Hedbys.\(^6\) Chlorpromazine and intravenous pentobarbital sodium were then given as needed to anesthetize the rabbits and allow them to be mounted in a stereotaxic headholder. Two 23 gauge needles were inserted into the anterior chamber of each eye by means of a modified Sears gun. One needle was attached by vinyl tubing to a Sanborn electronic pressure transducer. The second needle was attached through similar tubing to a Harvard infusion pump. The intraocular pressure was varied by altering the rate of inflow and was measured directly from the anterior chamber by the Sanborn transducer. The intraocular pressure was varied by altering the rate of inflow and was measured directly from the anterior chamber by the Sanborn transducer. Each time the intraocular pressure was altered, the infusion was regulated to cause the pressure to maintain a steady state while readings were taken. Applanation readings were taken from the corneal surface with the MacKay-Marg tonometer,\(^4\) recorded, and then compared with those readings taken simultaneously from the anterior chamber.

Experiment 2. Effect of corneal distortion by penetrating keratoplasty upon intraocular pressure measurements. New Zealand white rabbits weighing 4.0 to 5.0 kilograms were anesthetized with a combination of intramuscular chlorpromazine and intravenous pentobarbital sodium. Under the operating microscope, a 6.0 mm. penetrating keratoplasty was performed upon one eye of each rabbit, the other eye being left as a control. The surgical technique was similar to that described by Khodadoust.\(^7\)

Twenty-four to 48 hours after surgery the rabbits were again anesthetized and pressure measurements were made exactly as in Experiment 1.

An unsuccessful attempt was made to reproduce this experiment on enucleated grafted eyes. After keratoplasties were performed upon enucleated eyes, either human or rabbit, readable MacKay-Marg tracings could usually not be obtained. The reason for this is unclear. The authors surmise that some change may take place during the first 24 hours after keratoplasty in the living eye which does not take place in the enucleated eye and which permits one to obtain readable MacKay-Marg tracings. This would probably be a change in the anterior corneal curvature. Simply keeping enucleated, grafted eyes at normal intraocular pressure for 24 hours did not eliminate this difficulty. Our experience with human subjects has shown that, when one has been able to obtain readable MacKay-Marg tracings at 24 hours after keratoplasty, readable tracings remain obtainable thereafter. Furthermore, on the first clinic visit after suture removal, when accurate Goldmann applanation can be performed, the Goldmann measurements correlate well with those obtained by the MacKay-Marg instrument in human grafted eyes.\(^8\)

Results

1. Effect of corneal edema upon the intraocular pressure as measured by applanation with the MacKay-Marg tonometer. The corneal thickness of the treated eyes was between 2.0 and 3.5 times that of the control eye in every rabbit, illustrating the severity of the corneal edema produced by the freezing treatment. Fig. 1 plots the results of intraocular tension measurements by direct cannulation against those by applanation with the MacKay-Marg tonometer. In both the treated and the control groups, there was very good correlation between direct intraocular measurements and those taken by applanation of the corneal surface. The slope was 0.96 for the controls and 0.93 for the treated eyes. This was based upon 140 measurements taken from 10 eyes of 5 rabbits with a range from 9 to 59 mm. of mercury.

2. Effect of penetrating keratoplasty upon the intraocular pressure as measured by applanation with the MacKay-Marg tonometer. Measurements taken from direct cannulation of the anterior chamber correlate well with those taken by applanation of the corneal surface with the MacKay-Marg applanation tonometer (Fig. 2). The slope was 0.94 for the control group and 0.91 for the treated group. This was based upon 110 measurements taken from 10 eyes of 5 rabbits with a range of 6 to 52 mm. of mercury. (When 2 measurements coincided only a single point appears on the graph.)

Discussion

These studies in rabbits indicate that neither severe stromal edema nor the corneal distortion produced by penetrating

\(^*\)Berkeley Tonometer Co., Model 205.
Fig. 2. Correlation of pressure measurements made by direct cannulation of the anterior chamber with those made by applanation with the MacKay-Marg tonometer on normal corneas and corneas 24 hours after penetrating keratoplasty. Normal eyes are represented in the upper graph and those after keratoplasty in the lower. The slope is 0.96 for the normal eyes and 0.93 for those with corneal transplants. These were calculated in the same manner as above. Correlation co-efficients were 0.98 and 0.99 for the normal and grafted eyes, respectively.

Keratoplasty alters the accuracy of the MacKay-Marg tonometer to a clinically significant degree. The difference between the treated and the control curve was never more than 2.5 mm. of mercury over a pressure range from 6 to 50 mm. of mercury.

Many types of corneal disease make accurate intraocular tension measurement by Goldmann applanation impossible. These include corneal edema with bullous keratopathy, congenital glaucoma (where pressure is measured under general anesthesia) irregular central corneal scars, and...
recent keratoplasty. The small footplate of the MacKay-Marg tonometer and the fact that it can be placed upon any portion of the cornea, so as to avoid scars or large bullae, make it reliable in many cases where the Goldmann or Schiötz instruments cannot be used. If the results reported here in rabbits are valid in human subjects, then the MacKay-Marg tonometer should be a valuable addition to the armamentarium of any ophthalmologist dealing with a large number of patients with corneal disease. This seems a reasonable assumption since readings on normal eyes have been shown valid in both man and rabbits by several authors.3,4

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REFERENCES