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 application 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 application 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...
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 Frigitone 2 mm. cryoprobe at -60° C.5

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 regulated to cause the pressure to remain between 2.0 and 3.5 mm. Hg. Applanation readings were taken from the corneal surface with the MacKay-Marg tonometer,7 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. The corneal thickness was measured in both the treated and the control eyes of each rabbit, illustrating the severity of the corneal edema produced by the freezing treatment. Fig. 1 shows the results of intraocular tension measurements by direct cannulation against those by application. In both the treated and the control groups, there was very good correlation between direct intraocular measurements and those taken by application of the corneal surface. The slope of the graph 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 of 9 to 59 mm. of mercury.

2. Effect of penetrating keratoplasty upon the intraocular pressure as measured by application with the MacKay-Marg tonometer. Measurements taken from direct cannulation of the anterior chamber correlate well with those taken by application of the corneal surface with the MacKay-Marg application tonometer (Fig. 2). The slope 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
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.\textsuperscript{3, 4}

The authors wish to express their appreciation to Drs. Herbert E. Kaufman and Melvin L. Rubin for their guidance and assistance in this study. We are very much indebted to Mr. Dalton E. White, M. T., for his technical help. Statistical analysis was performed by Dr. J. I. Thornby.

REFERENCES