GOLDMANN APPLANATION TONOMETRY VS. KOWA HAND-HELD APPLANATION TONOMETRY: A CORRELATIONAL STUDY

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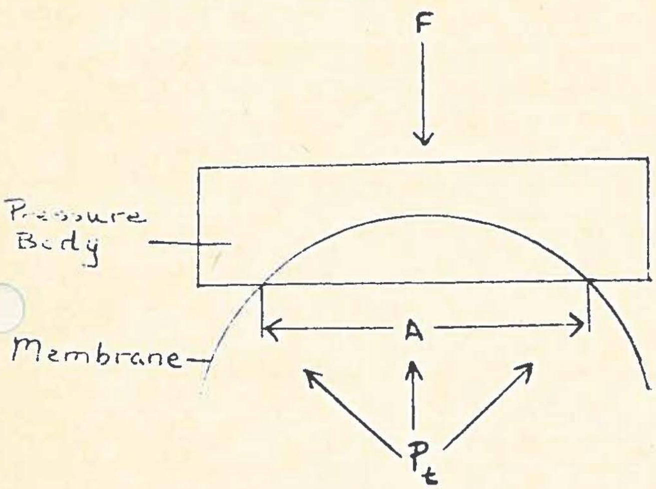
INTRODUCTION

It is generally accepted that Goldmann tonometry is, at this point in time, the most reliable clinical measure of intraocular pressure. However, Schiotz tonometry is still the most common method of measurement of intraocular pressure when a portable instrument is necessary. A standard Goldmann applanation tonometer is not easily portable, yet it is important in situations such as glaucoma screenings, bed-ridden patients, or patients with physical limitations to have an accurate tonometer. Since Schiotz tonometry has the disadvantage of being subject to errors of greater magnitude and variety than the Goldmann applanation tonometer, a more accurate and reliable portable tonometer may be desirable.

The purpose of this study is to compare a hand-held applanation tonometer to a standard Goldmann applanation tonometer and determine the correlation between the two instruments.

The Goldmann applanation tonometer, introduced in 1955, is based on the Imbert-Fick Law. This principle was used in tonometry as early as the 1800's, but never with much precision until the Goldmann tonometer. Goldmann, in development of a accurate and practical instrument, considered, in addition to the force required to flatten a specific area, several other complicating factors including: the effect of capillary attraction between the face of the applanation tonometer and the cornea, the stiffness of the cornea, the translation of force and area on the outer surface of the cornea to intraocular pressure at the inner surface of the cornea, and the influence of varying corneal curvatures, corneal astigmatism, fluid on the cornea, and scleral rigidity. In consideration of the physical properties of the cornea and the tear film, two terms were added to the Imbert-Fick equation to increase it's accuracy.



$P_t = F/A$ (Imbert-Fick eq.)

where P_t = total pressure

F = Force

A = Area

$P_t = F/A - P_m + P_n$

(Goldmann's Imbert-Fick eq.)

where P_m = pressure caused by the characteristic rigidity of the eye.

Pn = factor considering pressure which depends on surface tension of the liquid and the wetting properties of the cornea and flattening surface of the pressure body.

Note, since the pressure on the eye is affected by only the measuring pressure, the rigidity of the eye is not as an important factor in applanation tonometry as it is in indentation tonometry. Provided a measuring error of 2% was accepted, Goldmann and Schmidt concluded that an applanation area of 3.06mm provided the best results.

Mechanics of the Goldmann include a sensitive spring or counterpoise balance to measure the applied force and a pre-set split-field device establishes the applanated area at 3.06mm. This same mechanism is used with the hand-held device, which also has the advantages of being portable, not requiring a biomicroscope, and allowing measurements with the patient either upright or supine.

PROCEDURE

The hand-held tonometer used in this study was a Kowa. The Kowa is one of several portable tonometers available which have been designed based on the same principle as the Goldmann applanation tonometer. This particular instrument was used strictly because of its availability at the FSC Optometry Clinic. The standard Goldmann tonometer which the hand-held instrument was being compared to was a Haag-Streit. The Haag-Streit was chosen due to it's interchangeability with several of the slit-lamp biomicroscopes in the clinic.

The subjects in the study were either clinic patients at the College of Optometry, or students in the optometry or optometric technician programs. All measurements of intraocular pressure were taken by one observer - myself.

The following procedure was used in the collection of data: One drop of Fluress was instilled in each of the subject's eyes, and tonometry readings were started within thirty seconds to one minute. Standard procedure was followed for Goldmann tonometry with the exception that the calibration dial was not started each time on 10mmHg. The method of measurement with the Kowa hand-held instrument was the same as with the Goldmann, with the exception that alignment of the instrument was accomplished by hand rather than by adjustment of a slit-lamp biomicroscope. Again the calibration dial was not pre-set in any one position. Varying the initial pressure on the calibration dial was intentional to decrease my awareness of pressure readings until after the tonometer mires were determined to be aligned. This was to decrease any bias regarding correlation of the two instruments. The pre-test setting of the calibration dial however, was never less than 7mmHg or more than 13mmHg. The order of testing was randomly varied so some subjects had the hand-held tonometry performed first and then the standard Goldmann, and others had the standard Goldmann performed followed by the hand-held tonometry. This was to minimize any artifacts in correlation between the two instruments that may have been created due to elapsed time between instillation of Fluress and time of testing. For example, as the concentration of Fluress in the tears decreases with time, the mires will appear thinner and can therefore create lower readings. This was not felt to be a significant factor in this study as both tests were run in a total time of not more than approximately two minutes. Tonometry measurments were taken on both eyes with one instrument followed by tonometry measurements of both eyes with the remaining instrument. Only one reading was taken per eye with each instrument, unless there was a discrepancy between the two eyes with one instrument. If one instrument indicated a discrepancy of more than 2mmHg between the two eyes, the readings were rechecked for their repeatability. In the situation of pulse pressure variation affecting mire alignment, the mid-point of the pulse pressure variation was taken as the reading.

ANALYSIS OF DATA

A total of fifty individuals participated in the study consisting of 18 females and 32 males, ages 15-89. The study included 100 eyes with one Kowa measurement and one Goldmann measurement per eye. Forty-eight eyes had Goldmann measurements taken first, and fifty-two eyes had Kowa measurements taken first.

Data from the study is shown in Table I. The Kowa measurements were designated K, while the Goldmann measurements were designated G. In analyzing the data, a Pearson correlation coefficient (r) was computed and found to be r = .8929. This indicates a very high correlation between the Kowa and Goldmann instruments, and from this, one could assume a high predictability of results would exist between the two instruments. Computed means for K and G were $\bar{K} = 12.23$ and $\bar{G} = 12.09$, with standard deviations $S_K = 3.205$ and $S_G = 2.985$. In order to compare the means of the two samples, a t-test was computed and found to be insignificant at the $p > .05$ level. This indicated any difference in readings between the two instruments was likely statistically insignificant.

CONCLUSION

Considering the results of the Pearson coefficient, t-test, and means and standard deviations between the two sets of data, it was concluded that the Kowa hand-held tonometer is a highly reliable means of measuring intraocular pressure. The data would indicate the Kowa hand-held tonometer is as accurate and reliable as the Goldmann, which has long been considered the standard of reference in tonometry. With this in mind, the hand-held applanation tonometer should be considered a desirable alternative to the more popular Schiotz indentation tonometer in situations where a portable tonometer is required. The only likely disadvantage of a hand-held applanation tonometer compared to a Schiotz tonometer, would be the cost. At this time, the Kowa is approximately $750.00, whereas the Schiotz is around $200.00

TABLE I

K = Kowa $\bar{K}$ = 12.23 S_K = 3.205 r = .8929
G = Goldmann $\bar{G}$ = 12.09 S_G = 2.958

	K	G		K	G		K	G
1.	12	10	35.	16	14	68.	11	9
2.	12	12	36.	16	14	69.	13	10
3.	10	9	37.	11	13	70.	12	10
4.	10	9	38.	12	11	71.	13	12
5.	10	11	39.	11	10	72.	12	11
6.	10	11	40.	12	10	73.	9	9
7.	8	11	41.	15	13	74.	8	9
8.	8	11	42.	12	12	75.	9	10
9.	11	13	43.	13	15	76.	9	10
10.	11	13	44.	13	14	77.	9	8
11.	14	13	45.	13.5	14	78.	9	8
12.	13	12	46.	13.5	15	79.	12	10
13.	8	9	47.	11	11	80.	12	10
14.	8	10	48.	14	9	81.	10	12
15.	14	14	49.	11	11	82.	10	12
16.	14	14	50.	13	10	83.	13	13
17.	3	5	51.	20	20	84.	13	13
18.	3	5	52.	20	20	85.	12	11
19.	17	18	53.	11	11	86.	11	11
20.	18	17	54.	11	11	87.	10	11
21.	12	11	55.	10	11	88.	10	11
22.	11	10	56.	10	13	89.	10	12
23.	17	15	57.	9	10	90.	10	10
24.	16	14	58.	9	10	91.	15	13
25.	14	15	59.	10.5	12	92.	14	13
26.	14	14	60.	10.5	11	93.	10	9
27.	15	15	61.	10	10	94.	10	9
28.	15	15	62.	10	10	95.	18	18
29.	20	19	63.	12	12	96.	18	18
30.	21	21	64.	12	12	97.	12	12
31.	10	9	65.	13	12	98.	12	12
32.	16	16	66.	13	12	99.	17	16
33.	15	15	67.	11	8	100.	16	15
34.	15	15						

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