Measurement of Intraocular Pressure in Pig's Eyes Using a New Tonometer Prototype

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Abstract- **We have developed a new tonometer prototype that may prove useful for non-invasive self-tonometry. The device measures the IOP by recording the force required to deform the cornea as function of distance. The goal of this experiment was to measure the IOP on porcine eyes with the new tonometer prototype. The IOP was a measured directly from the cornea of porcine's eyes with different IOPs. These preliminary data demonstrate the clinical potential of home self-tonometry. Intraocular pressure (IOP) monitoring has revealed that diurnal fluctuations in IOP are a significant independent risk for glaucoma progression. The development of a non-invasive self-tonometer and a clinical method for its use by the patient at home will help in the management of glaucoma progression.**

I. INTRODUCTION

Elevated intraocular pressure (IOP) is not synonymous with glaucoma, but rather is the most important risk factor known for the development and progression of glaucomatous damage. Glaucoma is a disease caused by intraocular pressure. The elevated IOP damages and destroys the axons of the optic nerve, leading to progressive blindness.

Typical clinical tonometers measure the IOP directly from the cornea, which requires anesthetization of the eye. The prohibition of topical anesthetic for home use and the difficulty for patients to applanate their own cornea is a barrier in the use of existing tonometers for home monitoring. In actuality, most patients with glaucoma have their IOP monitored at hospital and clinics no more frequently that once every three months. Sporadic measurements of IOP taken at the ophthalmologist's office may be unreliable because they do not reflect the peak pressure or pressure variations.

IOP monitoring has revealed that a strong and significant risk is associated with fluctuations in IOP. Diurnal fluctuations have an effect over and above those of other known strong risk factors for progression. Asrani and colleagues showed that large fluctuations in diurnal IOP (10+2.9 mm Hg) are a risk for glaucoma progression [1]. Zeimer and colleagues conclude that peaks in IOP are associated with wakening and they disappear before the patient can reach the clinic and may have an effect on loss of vision [2].

Diurnal fluctuations in IOP are a risk factor that can only be measured outside of the clinic; therefore, the implementation of an effective tonometry method that permits the patient to measure their diurnal IOP daily could help in constant monitoring of IOP and management of glaucoma. The development of a non-invasive self-tonometer is the key in helping the clinician monitor and control the visual damage caused by elevated IOP.

II. METHODOLOGY

All clinical tonometers measure IOP by relating a deformation of the globe to the force responsible for the deformation. Our study bases its concept on the modified Imbert-Fick law that states that a force (W) applied against a sphere equals the pressure in the sphere (Pt) times the area flattened (Applanated) by the external force (A) [3].

$$W=Pt*A$$

Studies have demonstrated that when a=7.35 mm^2, internal applanation area is obtained the diameter of the external area of corneal applanation is 3.06 mm which is used in standard instruments [3]. A custom tip with this dimension is used in this study.

Basically, this new tonometer prototype measures the force applied directly on the cornea as a function of the displacement of the tip into the cornea. A conversion is done to change the force in mg to pressure (mm Hg) using the following conversion.

$$P\ (\text{mm Hg}) = 10.0797(\text{mm Hg/g}) * M\ (\text{g})$$

A force sensor (strain gauge), which measures small forces, was integrated with a potentiometer, which measures changes in distance. Both signals are time synchronized by a custom Lab-view program. The Lab-view program processes and compiles the data at a sampling rate of 1000 samples per second. The potentiometer is a commercial device with a sensitivity of 2.4 mV and fed by a 1.5V power supply. Fig.2 shows the potentiometer calibration curve. The force sensor (model AE801) is designed to read micro forces. It is a silicon technology strain gauge with ion-implanted resistors, with a gauge factor of 200, a load capacity of 12.2 grams and a full-scale output of 30 mV/V. It is fed by a 4.5V power supply. Fig.3 shows the force sensor calibration curve.

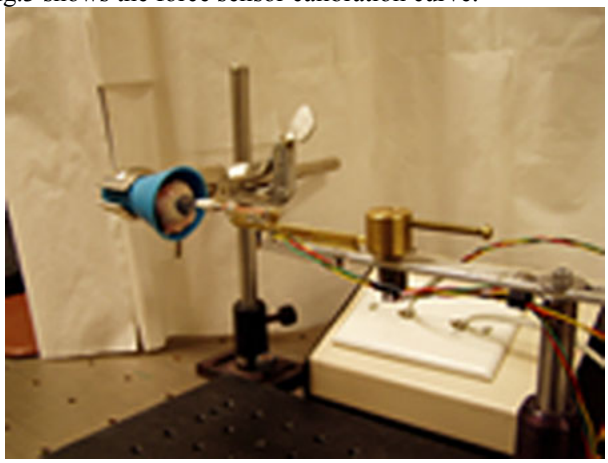


Fig.1 Photograph of Tonometer and Porcine Eye.

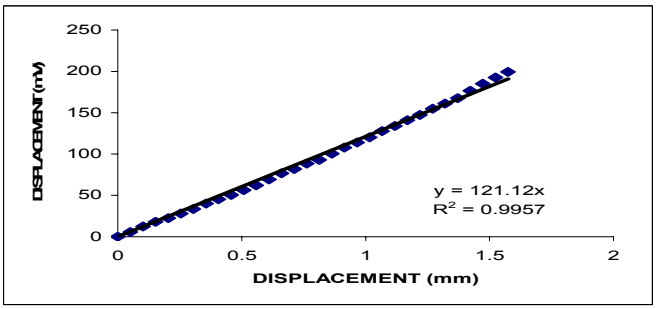


Fig. 2 Displacement calibration curve.

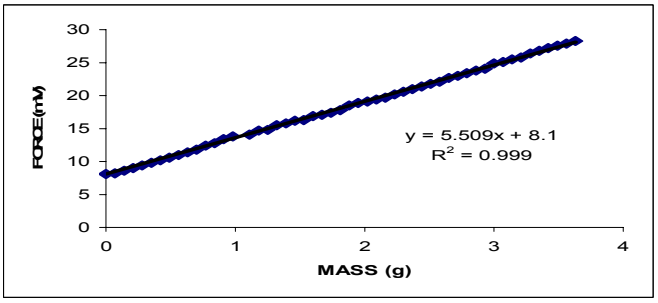


Fig. 3 Force calibration curve.

This study investigated the IOP of porcine eyes with different IOPs. A manometer was attached to enucleated eyes by a needle inserted through the optical nerve. A stopcock was placed between the needle and manometer, and a reservoir (water) was used to adjust the pressure in the eye. When the desire pressure was introduced into the eye the stopcock was closed. The custom tip was applied directly onto the cornea ad the force was gently increased until the necessary corneal deformation took place. Two trials of measurement were realized for each different IOP.

III. RESULTS

Fig.4 illustrates a summary of the relationship between pressure and distance for different IOP pressures. As the displacement of the tip increases the pressure increases linearly and there is an inflection at the point when the tip flattened the cornea completely, beyond this point there is a linear relationship with different slope. We observed a reproducible pattern from repeated measurements conditions.

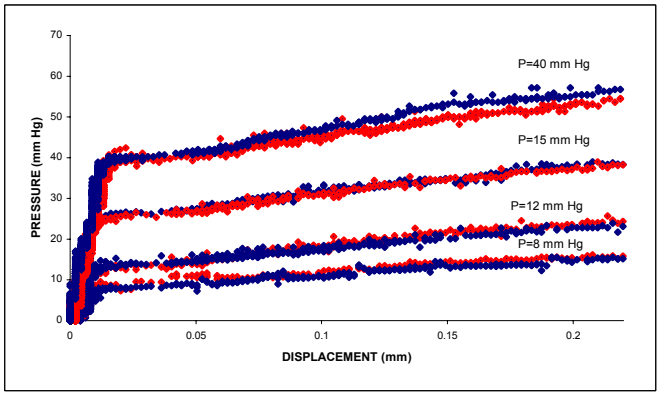
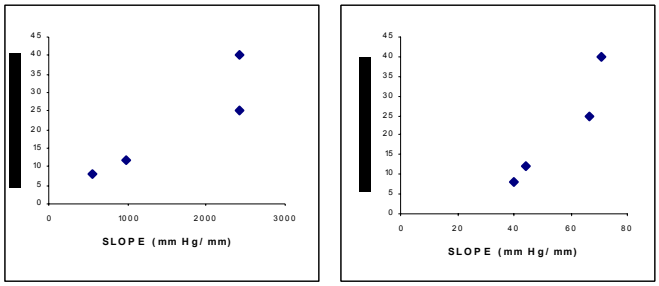


Fig. 3 Pressure-displacement relationship.

Fig.5 shows the relationship between curve slopes as a function of the pressure recorded. The first section of the linear relationship between the pressure and the displacement is shown in (a) and the second part after the inflection point is shown in (b).



(a) (b)

Fig. 5 First section (a). Second section (b).

IV. DISCUSSION

Preliminary data collected on animal studies (porcine' eyes) shows that the relationship of pressure applied as a function of distance hasan inflection point at the known IOP and under the same conditions a reproducible pattern is obtained.

In addition, further studies are necessary in humans directly on the cornea and the eyelid, and in comparison to the Goldmann reading which is clinically the "gold standard" will be crucial to confirm that the inflection point through the eyelid correlates with the IOP.

The results suggest that this new tonometer prototype could be used to measure the IOP of humans directly from the cornea and it could be considered clinically as a non-invasive self-tonometric method.

The development of a non-invasive self-tonometer at an affordable price and easily operated that could be use by patients at home for monitoring the diurnal fluctuations in their IOP would help in the management of glaucoma progression.

ACKNOWLEDGEMENT

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