INTRAOCULAR PRESSURE MEASUREMENT COMBINED WITH GONIOSCOPIC ANALYSIS

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ABSTRACT

Glaucoma is an ocular disease, and the type of the disease can be diagnosed with tonometry and gonioscopy. In India and China, angle-closure glaucoma (ACG) is more prevalent than open-angle glaucoma (OAG). Gonioscopy can diagnose the type of glaucoma efficiently. In all eye care clinics, tonometry is carried out effectively. But, due to a lack of amicable technology or training, gonioscopy is not regularly performed on all patients, leading to the wrong diagnosis of ACG as OAG. A proof of concept is proposed using an air-filled ball as an eye model, followed by an animal model (goat eye). The role of tonometer to measure the value equivalent to the pressure in the eye model/goat eye is accomplished by placing a vibration sensor on the outer structure of gonio lens. The output of the sensor during the bouncing back action of the eye model/eye after the force on the it is released, is recorded and the relation between the eye pressure and the voltage output is derived. The result summarizes that an increase in pressure will increase the magnitude of vibration sensor output. The new technology introduced will measure eye pressure and the existing three-mirror gonio lens is utilized intact such that the path to view the anterior chamber angle is not distorted.

Keywords:

Tonometry, gonioscopy, Open-angle glaucoma, Angle-closure glaucoma, piezo vibration sensor.

1. INTRODUCTION

Glaucoma is a group of diseases with a characteristic optic neuropathy with associated visual function loss. According to World Health Organization, glaucoma is the second leading cause of blindness after cataracts. The study by George et al. [1] reveals that every 8th Indian above 40 years is at risk for glaucoma, with a higher risk of angle-closure glaucoma. Sathyamangalam et al. [2] brief glaucoma disease burden estimated at 25 million in 2012 is projected to reach over 100 million by 2040, thus emerging into a substantial public health challenge. Lovejoy et al. [3] explain a system used to measure any test object's vibration. The system includes a probe sensor fitting, a microphone, and an ultrasonic speaker. The microphone detects a Doppler shift in a frequency proportional to the target shaft velocity using the system. Methods adopted by the successful tonometer [4-5], such as the Sensimed triggerfish tonometer, Icare tonometer, and Mackay Marg tonometer, are referred to and utilized during the new technology evolution. A survey was carried out by Choudhari et al. [6] in India to study the pattern of glaucoma specialists. It was found that 82.6% reported carrying out gonioscopy in all patients with or those with suspects glaucoma. The remaining 14.4 % will perform gonioscopy only when the IOP is high or may not perform the test. Hence, the proposed technology will address these problems by applying best-fit technologies by combining both testing procedures in a single instrument. This innovation is not addressed on the clinical as well as on the industrial side. But separate devices exist to perform tonometry and gonioscopy.

2. METHODOLOGY

The entire work to combine both the glaucoma testing procedures is achieved by dividing the whole work into the following categories. The pressure inside the ball is increased using a hand pump, measured using a low air pressure sensor. The interface of the LCD screen with an Arduino Uno microcontroller to display pressure inside the ball. Fresh air is pumped into the ball by using an ordinary air pump. A low air pressure sensor, namely a board mount sensor (TBP-D-AN-N-150PG-U-C-V), is used to measure air pressure inside the ball. This sensor is linear in the low-pressure range from 0-1 PSI. The output of the air pressure sensor is fed to analog input pins A0, A1 of the Arduino Uno microcontroller, which is interfaced with the LCD unit. The output of the air pressure sensor is in terms of voltage. The selection and the placement of the sensor on the goniolens is the major challenge in the The sensor will measure the value equivalent to the IOP of the eye. After experimenting with different sensors, the vibration sensor is the optimal solution, as Bernstein et al. described [7] and Zhang et al. [8]. Minisense 100 piezo-based vibration sensor has high voltage sensitivity up to 1V/g, low cost, highly linear, and horizontal mounting shielded construction. The next stage is to design a supporting structure to place the vibration sensor on goniolens. The supporting structure on the anterior side is aluminium. On the posterior side is acrylic, and both these structures are screwed to form a tight supporting structure to hold the vibration sensor. The design and image of the piezo vibration sensor's embedment on the goniolens are shown in Fig. 1. The placement of the vibration sensor was made cautiously so as not to obscure the parabolic mirror position (used for angle structure visualization) in the Goldmann three-mirror goniolens. Fig. 1 explains the embedment of the vibration sensor on goniolens. The vibration sensor is placed upon the outer aluminium surface of the goniolens using a supporting structure and will not obstruct the light path through the goniolens. Hence, the gonioscopy procedure may not be affected. The sensor embeded on goniolens is situated on the surface of the ball. Force applied on the surface of goniolens will deform the surface of the ball. A pneumatic system is used to apply a constant force on the ball during the testing procedure. The pneumatic system comprises the cylinder, push-button, flow control, and quick exhaust valve. When the push button is pressed, it releases the pressurized air onto the cylinder, and due to the pressure of the air, the cylinder experiences a force and moves down.

1- Gonio lens
2-Aluminium Holder
3-Sensor
4- Acrylic Holder
5- Sensor terminals.

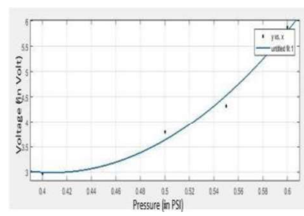


Fig. 1: Image of sensor embedded on goniolens   Plot 1: Voltage output of the sensor

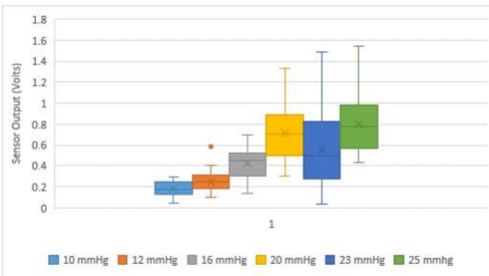
The LTC-6240 operational amplifier from linear technology is used with a gain of 6 to amplify the small signal output of the vibration sensor. LTC 6240 is a CMOS op-amp with input bias current of 12pA, high input resistance 10* 10e12Ω, very low noise level up-to 550nV (peak-peak) and very low offset voltage. The sensor behaves like an active capacitor of value 244pF, and a high pass filter is designed by adding high resistance of 380MΩ parallel to the output of the sensor. Hence the cut-off frequency of the filter designed is 2Hz. The amplified output from the operational amplifier is continuously recorded in the LabVIEW using NI DAQ 6001 data acquisition card. The technology to measure the pressure using ball as the eye model is verified. Further, the investigation is carried out on the animal model. The experimentation involved dead goat eyes. The goat's eyes are taken immediately after its death. The eyes are used within 3 hours of its death before fragmentation starts. A standard manometer setup is established to apply a known pressure into the goat eye. An ICARE tonometer is used to measure the IOP to standardize the manometer. Thus, the scale used in the manometer is standardized such that each division on the scale corresponds to the value of pressure (IOP) by carrying out the testing with 30 samples of goat eyes. Hence standard pressure can be applied to the goat eye using the developed manometer setup. For experimentation, goniolens embedded with the sensor is placed on the ball. Force is then applied to the surface of the ball. A known amount of pressure will be developed inside the ball and is measured by the air pressure sensor (TBP-D-AN-N-150PG-U-C-V) placed within it. The readings of the air pressure sensor are fed to analog input pins of the Arduino Uno microcontroller, and air pressure (PSI) will be continuously displayed on the LCD screen interfaced with the Arduino Uno microcontroller.

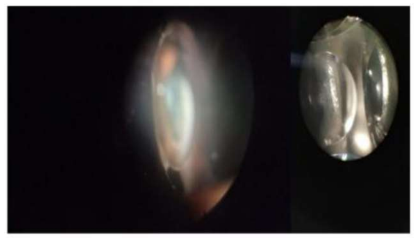
During the applanation force, a constant force is applied with the pneumatic system. This force results in the deformation (bending) of the ball. But the displaced ball will bounce back and settle to its position immediately. The amount of bouncing back of the ball is dependent on the pressure inside the ball. The DAQ card is used to tap the signals from the sensor and then fed into the LabVIEW programming paradigm. The process is continued on the animal model, such as goat eyes. The investigation with the goat eye is carried out by impinging a standard amount of pressure into the goat eye using the standard manometer setup. Many goat eye samples are taken, the experiment is repeated at 10 mmHg, 12 mmHg, 16 mmHg, 20 mmHg and analysis are carried out.

3. RESULTS

In the initial stage of experimentation, the ball is used as an eye model to verify the technology of tonometry by embedding the vibration sensor on goniolens. The increase in the pressure in the ball from 0 to 1 PSI will result in increased sensor voltage output from 3V to 6V. Plot 1 explains that the sensor's output increases as the pressure inside the ball increases. The result proves that the magnitude of sensor output is directly proportional to the pressure in the eye model.

Goat eyes are used for animal model experimentation. The animal experiment results in plot 2 explaining the relationship between the IOP of the eye with the vibration sensor output and proves that the magnitude of sensor output increases with an increase in the IOP of the eye. The results conclude that the sensor's voltage output is of lower amplitude than the experiment results with the ball. This relation is further employed to estimate the IOP of the eye by reading the voltage output of the sensor. Hence, the role of the tonometer to estimate the IOP of the eye is developed.





Plot 2: Voltage output of the sensor

Fig. 2: Angle structure visualization using Tonogonio.

Fig. 2 shows the angle structure of a goat eyes as seen through device developed "tonogonio". The procedure to visualize the angle structure begins by introducing a dead goat eye before the fragmentation starts and before the elasticity of the dead goat eye is lost. The airgap between the goat eye and tonogonio is filled with water. This adds smoothness and moisture content to the eye sample. The slit lamp is used to focus light on the eye, while tonogonio is placed on the corner of the eye. Fig. 2 (a) depicts the visualization of the goat eye angle structure, whereas Fig. 2 (b) depicts the mirrors as seen via the goniolens, as well as the angle structure view. Fig. 2 (b) shows the angle structure as the dark shaded region when viewed through the three mirror goniolens. Thus, the claim of visibility of the angle structure during the tonogonio procedure is validated as part of the research.

The distance of travel of the eye model during the application of force on eye is inversely proportional to the pressure inside the ball/eye model, as described by Abreu et al. [9], and the present technology of measuring the bouncing back the ball/eye model is also dependent upon its pressure. The new technology has been validated such that, as the pressure inside the ball increases, the amount of deformation of the ball/eye for the prefixed amount of force will decrease, as explained by Abreu et al. [9], and will result in the more rigorous amount of bouncing back and hence higher magnitude of sensor output voltage. Thus, the ball will rebound actively and result in higher voltage output as the pressure inside the ball increases.

4. CONCLUSION

New technology has evolved which will derive the relationship between the pressure inside the ball/eye model and the vibration sensor output and hence can be utilized to work as a tonometer. Hence a single instrument is developed to perform both tonometry and gonioscopy procedure. A holder will be designed to situate the animal eye such that it will not move or displace from its position, other than bouncing in the vertical direction. Statistical analysis will be carried out using Minitab or SPSS software for the experimental results with goat eyes to drive the relationship between the IOP of the goat eye and the vibration sensor output. Validation will be done by comparing the results with golden standard methods such as the Goldmann Applanation tonometer or ICARE tonometer.

5. REFERENCES

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