TONO-GUN: Design and Development of a Miniature Non-Contact Air-Puff Tonometer for Intraocular Pressure Measurement

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ABSTRACT

Glaucoma remains one of the primary causes of irreversible blindness, and early detection along with monitoring of the condition is crucially dependent on the measurement of intraocular pressure. Conventional clinical-use tonometer are often bulky, expensive, and not suitable for personal use or measurements outside a clinic setting. The aim of this paper is to present a compact, non-contact air-puff tonometer for easy, portable, and hygienic IOP measurement.The corneal deformation in the proposed device is produced by a controlled air puff. A momentary pulse of air is applied on the surface of the cornea, causing it briefly to flatten. The air flow is then ceased and the pressure applied is measured and converted to millibar IOP values. Included in the system are a small air pump, pressure sensor, optical lighting, configuration for beam splitting, and a system for detection of the flattening of the cornea. TONO-GUN was to be designed in such a way that it would be easy to use, portable, and non-invasive. Its aim is providing an inexpensive, easily accessible alternative for screening of IOP in clinics, home care settings, and rural healthcare.

Keywords

Miniature air-puff system, non-invasive ocular pressure measurement, Portable tonometry device, Corneal deformation sensing, Handheld ophthalmic instrument, TONO-GUN.

1. INTRODUCTION

Measurement of intraocular pressure (IOP) is a fundamental requirement in ophthalmology, as abnormal IOP levels are closely associated with the onset and progression of glaucoma. Regular IOP screening is essential for early diagnosis; however, access to reliable tonometry is often limited due to the size, cost, and clinical dependency of conventional devices. Most existing tonometer are designed for hospital environments and require trained professionals, controlled settings, or direct contact with the eye, this reduces their usage in general screening, home care, and rural health facilities.

However, there are some limitations in the existing tonometer, which include invasive procedures and physical contact with the eye. The aim of this work is to introduce TONO-GUN, a non-contact air puff tonometer that is compact and portable and easy to use to overcome these limitations. The proposed tonometer makes use of the air puff system in which the cornea shape is temporarily altered to calculate the intraocular pressure without resorting to invasive procedures and physical contact. The proposed system is intended to fulfil the requirements of a portable and low-cost tonometry system for use in a medical setup as well as in community eye screening at home.

2. LITERATURE SURVEY

To assess the intraocular pressure in vitrectomies patients, the authors of the paper [1] compared the Tono Pen and air-puff tonometers. From the paper, it is evident that besides being able to accurately measure intraocular pressure, non-contact air-puff tonometer's have other advantages such as improved patient comfort and reduced risk of infection. The relevance of air-puff tonometry being employed in various settings is highlighted by the above study.

The authors of Paper [2] performed a comparison between the measurements from the traditional technique and air puff tonometry. High correlation was observed between the novel above methods, which suggest that the air-puff tonometry represents a useful tool for screening and get pre-diagnosis. Working with non-contact tonometers also emerged as a key factor in the clinical setting where comfort, speed and cleanliness were required.

In Paper [3], the modern non-contact tonometer, which is the focus of our analysis, was compared with the Goldmann applanation tonometer, which is the standard device for the measurement of intraocular pressure. The non-contact tonometer This Article has demonstrated that in spite of the small differences, the non-contact tonometer was still able to provide accurate and reliable data within acceptable levels. The authors have also emphasized the extra advantages of the non-contact tonometer in terms of improved patient compliance and cooperation because of the lack of direct eye contact and the reduced risk of cross-contamination and infection transmission. These results do indeed confirm the safety and accuracy of non-contact tonometer's in a busy clinic.

In Paper [4], the authors have discussed on designing and evaluating of a portable non-contact tonometry device for point-of-care and remote eye-health monitoring application. The authors have demonstrated miniaturized air puff systems with optical sensing and digital signal processing that can be used for accurate IOP measurement. The authors have further pointed out that issues like portability, low-power consumption and ease of use are crucial for the practical implementation of such systems in glaucoma screening programs in rural regions.

TABLE 1. COMPARISON OF THE PROPOSED SYSTEM WITH THE EXISTING SYSTEM

System Feature	**Digital Contact Tonometer (Tono-Pen)**	**Standard Non-Contact Tonometer**	**Proposed TONO-GUN (Handheld)**
Contactless Measurement	No	Yes	Yes
Portability/ Handheld	Yes	No	Yes
Real-time Digital Display	Yes	Yes	Yes
Historical data Storage	No	No	Yes
Low-Cost Design	No	No	Yes
Accuracy	High	High	High
Patient Comfort	Moderate	High	High
Safety	Moderate	High	High
Ease of Use	Moderate	High	High

3. MOTIVATION FOR THE NEED OF THIS PROJECT WORK

Motivation-This project work is motivated by the increasing demand for a safe, hygienic and non-contact approach to measure intraocular pressure for early management of glaucoma and related eye illnesses. The conventional methods of contact tonometry are done by touching the cornea directly and may be uncomfortable to the patient, anaesthetic eye-drops are required and as well, pose a risk of cross-infection. The disadvantages therefore point at a requirement for a non-contact approach that can obtain both safety and patient comfort.

The TONO-GUN system that is being developed in this project uses a method of controlled air puff and electronic sensing to measure the intraocular pressure in noncontact immersion.

4. PROPOSED SYSTEM MODEL

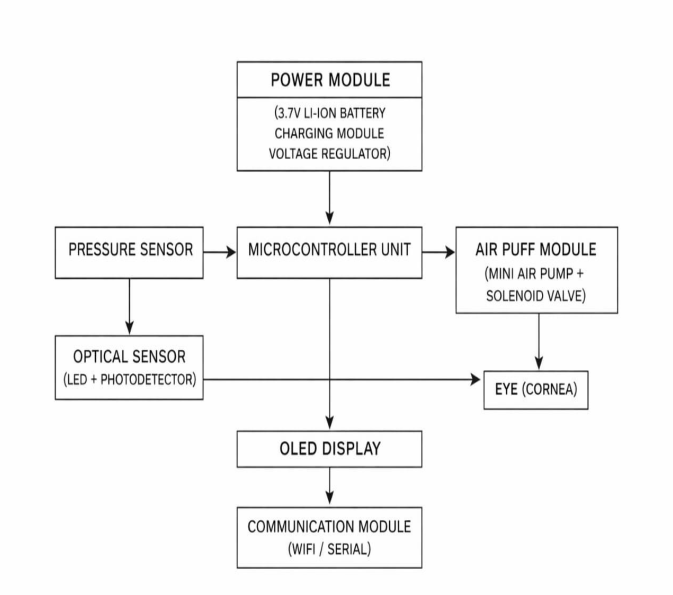

FIGURE 1: BLOCK DIAGRAM OF THE PROPOSED SYSTEM MODEL

Figure 1 The block diagram of the proposed TONO-GUN system. The system includes a power module, an air puff generation module, a pressure sensing module, an optical sensing module, a microcontroller module, and a display module and communication modules. Battery frame of the system is powered by a 3.7V rechargeable li-battery with TP4056 Type-C charging, and the voltage regulation circuit is utilised to supply all-modules stable power.

The air puff generation module includes, but is not limited to, a small-sized air pump and solenoid valve for inducing a precise amount of an air pulse to an eye to non-contact cause the cornea deformation in hygienic manner. The pressure sensing module is utilized for real-time measuring the input air pressure, and the optical sensing module adopts.

4.1. Data Acquisition and Simulation Model:

The TONO-GUN system operates by integrating controlled air puff delivery, optical detection and pressure sensing to provide an instant estimation of intraocular pressure. The complete process from acquiring the data to the appearance of the result at output is described below:

Air-Puff Generation: A small air-compressor is used to generate compressed air so that the generated air can be delivered by a solenoid valve. The opening interval time of the solenoid valve can he precisely controlled by the microcontroller to produce a constant air pulse to project onto the cornea.

Pressure Data Acquisition: The pressure sensor is reading the air pressure throughout the generating of the air puff. The felt pressure is transformed into an electrical signal, and it is proceeded and collected by the microcontroller.

Optical Detection:

The optical sensor measures corneal applanation by the reflective or interrupted light signals. The sensor detects the pressure at which the cornea applanates, and this signal is used as a reference that correlates measured air pressure values.

Microcontroller Processing:

Pressure sensor and optical sensor are read all the time by means of microcontroller. It correlates applanation time to the impressed air pressure by means of on-board processing algorithms to find out the intra ocular pressure (IOP) in mmHg.

Local Display Unit:

Once the measurement is finished the IOP result shows up instantaneously on OLED. The practitioner or user is thus able to see the results directly in a screening process.

Data Storage and Communication (Optional):

Once the feature is activated, it would become possible to transmit (wirelessly through Wi-Fi or by serial communication interfaces) the measured IOP data to a computer or cloud server that is then connected with the device. This enables safe archives and store of patient information as well as the possibility of monitoring long-term IOP trend, tele-ophthalmology applications.

Simulation and Verification:

Prior to full system implementation with the hardware, simply functions were simulated using Arduino IDE's serial monitor and custom test codes. These simulations have verified that the air puff timings were accurate, the synchronization of sensor signals was accurate, and the IOP result values were correct.

Integrated Model:

The full and solid system model associated with the integrated work of air puff current generation, pressure measuring

4.1.1. Pseudocode of Proposed System:

Step1:
Turn on all hardware components of the system, such as initializing the serial communication, pressure sensor, optical sensor, OLED display, air pump, and solenoid valve.

Step 2:
Turn on the system to standby mode and wait for the trigger signal from the user to begin the measurement process.

Step 3:
Operation of the pint-sized air pump and opening of the solenoid valve for an accurately controlled duration enables a uniform and reproducible pulse of air to be produced. The exposure time and amplitude of air puff are determined by the microcontroller to keep the cornea deformation safe and accurate.

Step 4:
The pressure sensor and the optical sensor are monitored extensively during the administration of the air puff. The pressure sensor monitors the instantaneous air pressure on the eye when establishing an optical path through the light conductivity (and then tracks variations in reflected infra-red light reflecting from curved cornea brought about by fluid injected).

Step 5:
The optical sensor signal is monitored to locate the corneal applanation moment which is coincident with maximum reflected light. At this time, the pressure sensor value corresponding to this moment is sampled and recorded as the applanation pressure.

Step 6:
The recorded applanation pressure is recalculated with calibration and conversion algorithms to derive the intraocular pressure (IOP) in units of millimeters of mercury (mmHg). This IOP value measured is the finished measurement result shown to the user

Step 7:
The real, time value of the reported Intraocular Pressure (IOP) measurement along with the system status is visibly displayed on the OLED to ensure a successful IOP measurement.

Step 8:
Facilitation of data storage and/or communications occurs next, where the IOP result is sent to a personal computer (PC) or cloud database via a communications interface. This allows for digital archival of patient information and greater analysis of that information later.

5. RESULTS & DISCUSSIONS

In this section, the performance of the proposed TONO-GUN system is evaluated through theoretical analysis and comparison with a conventional non-contact tonometer. The system is developed as a portable, cost-effective, and contactless solution for measuring intraocular pressure (IOP). By utilizing a controlled air-puff mechanism and sensor-based response analysis, the device aims to provide reliable and rapid screening of eye pressure. The results demonstrate the capability of the system to accurately distinguish between normal and elevated IOP levels, highlighting its potential application in early glaucoma detection, especially in low-resource and community healthcare settings.

5.1 HARDWARE IMPLIMENTATION

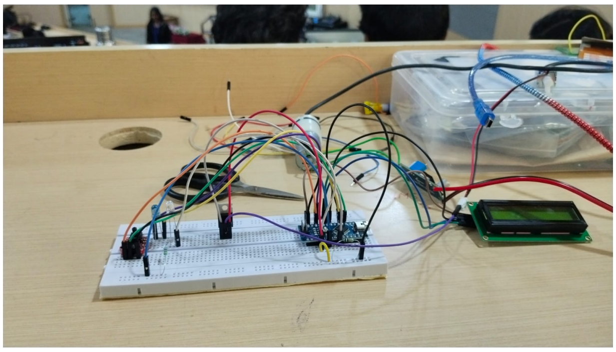

FIGURE 2: HARDWARE PROTOTYPE OF TONO–GUN SHOWING AIR PUMP, SOLINOID VALVE, CONTROL CIRCUIT AND DISPLAY MODULE

From **Figure 2,** the hardware implementation of the TONO-GUN prototype is illustrated, showcasing the integration of key components such as the air pump, solenoid valve, silicone tubing, microcontroller, and OLED display. The air pump generates pressurized air, which is precisely controlled by the solenoid valve to produce a short air puff directed through the nozzle. The microcontroller manages the timing and operation of the system, while the MOSFET driver ensures efficient switching of the components. A buck converter is used to regulate the voltage supply for stable performance. The prototype was assembled and tested successfully, demonstrating controlled air puff generation and reliable system operation, thereby validating the feasibility of the proposed portable intraocular pressure measurement device.

TABLE 2: EXAMPLE INPUT PARAMETERS

SI.No	IOP (Input Parameters)	Unit
1	12.5	mmHg
2	16.2	mmHg
3	19.8	mmHg
4	23.4	mmHg
5	28.7	mmHg

From **Table 2**, the input IOP values range from normal to elevated levels. The TONO-GUN system can process these values effectively and demonstrates its ability to detect variations in intraocular pressure, which is essential for glaucoma screening.

TABLE 3: INTRAOCULAR PRESSURE (IOP) STATUS

SI.No	IOP Status	System Indication
1	Normal (10–21 mmHg)	Display
2	Slightly Elevated (21–25 mmHg)	Display
3	High IOP (>25 mmHg)	Display

From **Table 3**, the system categorizes intraocular pressure into different levels based on predefined threshold values. The results are displayed on an OLED screen, enabling quick and easy interpretation. This helps in early detection of abnormal eye pressure conditions.

TABLE 4: COMPARISON OF THE PROPOSED SYSTEM AND THE CONVENTIONAL SYSTEM WITH THRESHOLD STATUS

Patient ID	Proposed System (mmHg)	Conventional System (mmHg)	Status
P001	12.6	12.7	Normal
P002	16.1	16.2	Normal
P003	19.7	19.8	Normal
P004	23.3	23.4	Slightly Elevated
P005	28.6	28.7	High IOP
P006	30.1	30.2	High IOP
P007	32.4	32.5	High IOP
P008	35.0	35.1	High IOP
P009	37.2	37.3	High IOP
P010	40.0	39.9	High IOP

From **Table 4**, the proposed system shows results very close to the conventional system with a minimal difference of approximately ±0.1 mmHg. This indicates that the TONO-GUN system has good accuracy and reliability for screening purposes.

6. CONCLUSION

The TONO-GUN is a portable, non-contact device designed for measuring intraocular pressure. It operates by delivering a controlled air puff and analysing the corneal response using sensors, thereby estimating the eye pressure without direct contact.

The system is compact, easy to use, and provides instant results on an OLED display. Its contactless nature improves patient comfort and reduces the risk of infection transmission during mass screening.

Due to its low cost and portability, the TONO-GUN is suitable for use in clinics, rural healthcare settings, and community screening programs. Overall, it offers a reliable and efficient solution for early detection of glaucoma and other eye pressure-related conditions.

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