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The Potential of Noninvasive Micro-electromechanical Systems in Intraocular Pressure

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Abstract*: This paper assesses the incidence of glaucoma in the developing world and how Microelectromechanical Systems (MEMS) can be used to mitigate the condition. Intraocular Pressure (IOP) is a leading cause of glaucoma and is occasioned by the failure of proper drainage of the aqueous humor fluid. This leads to irreparable damage to the lens and the retina, which cause permanent blindness. It is prevalent in areas where mainstream medication and ophthalmology care is above the access and penetration of high income communities. Methods like palpitations, manometry, and telemetry have been used to measure the pressure. They are intrusive and require a personal commitment to regular checkups. However, MEMS stand a chance to offer less intrusive and highly efficacious devices to measure and report IOP. The contact lenses and on-chip sensors devices allow easy monitoring of IOP and allow constant communication of the changes to an external device. This device can be easily monitored by the patient since the instruments allows self-reporting of the condition. This makes it suitable to be used in areas where low accessibility and penetration of ophthalmologic treatment is low yet crucially needed. In addition, it taps directly to available technology of mobile and internet access thus making it feasible in its application.

Keywords: Microelectromechanical Systems (MEMS), Intraocular Pressure (IOP), Glaucoma, measurement, and Reporting.

I. INTRODUCTION

Glaucoma is the second leading cause of blindness in developing countries after cataracts. It is responsible for 30% of all blindness cases [3-5]. However, the main hindrance in its resolution lies in the low awareness and the progression of the condition. Glaucoma is caused by an imbalance in the inflow and outflow of the aqueous humor resulting in the increase in intraocular pressure [6]. This, in turn, can result in irreversible damage to the lens or the optic nerve, thus resulting in blindness. This condition occurs with minimal pain and disturbances thus delaying its attendance. Many patients approach eye clinics near to the critical stage where their condition cannot be helped [7]. Since it is painless, little actions are taken to minimize the accumulation of pressure to dangerous levels. Reports indicate that many patients in these countries visit when pressure is approaching 45 mmHg well above the normal 25 mmHg of intraocular pressure [8]. The other hindrance lies in the under-equipped eye clinics which are focused on treatment as opposed to prevention. The buildup of pressure can be resolved through surgery. This is done to divert the excess fluid and collect the draining mechanism resulting in the build up pressure [20]. However, many patients are reluctant to have this surgery, especially when it does not resolve their partial blindness. Those blinded by the condition in one eye reluctantly oppose to operation in their good eye with the fear that it may lead to complications. This results in eventual blindness, which cannot be prevented. Laser surgery is promising but still suffers from a limitation of equipment and staffing [9]. The use of eye drops is the most prevalent method of treatment. Although this method is very prevalent, the eye drops are expensive and prone to misuse. They are also high chances of the drops being of no use due to expiration or improper handling by the patients. This leaves the use of MEMS to take advantage of the extensive use of mobile technology and internet connection to ensure proper measurement reporting and attendance of IOP [10]. It mediates the interaction between patients and ophthalmologists for continuous measurement of IOP and earlier detection and prevention of glaucoma.

II. PROPOSED SYSTEM

Developing countries have a lag in expertise and personnel access for many traditional medical inventions. Classical methods for measuring iop have been in application for a long time. However, it is their access to many people suffering in developing countries that leaves a gap in their efficacy. They include; manometry and tonometry. Palpation is another method which is a primitive way of measuring the IOP. It involves the use of one's digit to press against the cornea of a closed eye. Practice can result in sufficient learning, where the proper assessment of the eye pressure build-up is possible [11]. However, limitations abound in this method since it does not differentiate the source of pressure and thus acts indiscriminately. The other two, however, are of significant development which is inaccessible in many developing parts of the world.

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A. Manometry

It is an invasive procedure that is used to measure the IOP in the laboratory consistently. The figures obtained are used to assess the level of the IOP, which informs the actions that are taken subsequently. The experimental pharmacological experimentations that are thus carried out are thus difficult to achieve on a widespread scale [2, 8].

B. Tonometry

Based on the analysis of the ease of use as well as the participation levels needed, the tow methods appear to shows great inhibition in terms of widespread application in areas with low ophthalmology access and preventive medication culture. The insidious development and the irreversible damage of the unmonitored IOP makes the condition lethal to many individuals. Therefore, the two methods are thus limited in the following spheres; They are overly invasive to the patient and require more than a furtive concern of one's medication. The use of manometry requires hours of observation in the laboratory in order to access a workable measurement that would act as a guide to determining IOP pressure [13]. This creates a strenuous investment in part of the patient which in terms limits the efficacy of the medical approach in tempering the prevalence of glaucoma [17]. Since the condition is painless, there are the costs in getting the monitoring for a condition that lacks any current limitation to ones daily activities. Tonometry also acts as a less invasive alternative but retains the vestiges of manometry in terms of constant visit and invasive measurements of the cornea. The methods are also discrete which is detrimental in measuring IOP. They require periodic measurement which is dependent on the visits made by the patient to the opticians in the area. Developing countries lack in this culture of medical investment for conditions that are not immediately limiting. The jury is out on the real causes of glaucoma with IOP having the highest attribution.IOP varies greatly which may not provide reliable data to make an informed decision to the ophthalmologists [23-25]. Lastly, the method lacks leverage in countries with less scalable medical supplies and unbounded ignorance of their own health. Developing countries lack the professional capability to have advanced managed of nuanced ailments such as glaucoma [1, 13, 22]. This makes the supply of the services limited in only the populous areas of these nations. In addition, the ignorance is made worse by lack of awareness and opposition to the invasive techniques that are widely available. Technology has been an effective strategy to leverage provision of services in developing countries. It makes for easy penetration and unlike other active monitoring technology available, it is affordable through leverage of reporting and monitoring technologies through shared interfaces with the medical providers [12, 18, 19, 21]

The noninvasive MEMS leverage describes the intervention in the measurement of IOP using MEMS in developing countries. The advancement of VLSI in the digital system is the reason for these developments. The technologies described have the potential to make drastic improvements in the field of ophthalmology as an improvement of current methods. The evaluation should thus be interpreted from the viewpoint of technology advancement in the use of MEMS in medical solutions and the pairing of the technology with the existing infrastructures. The latter focuses more on means of reporting, providing a medicating interface for patients and doctors and providing a foundation for self-medication in cases to allows the evasive scalability of treatment in such rife medical conditions such as Glaucoma [14-16]. This comes from the recognition of increased opacity of some conditions to permit proper diagnosis and proper medication of a condition. MEMS offer a good start in interfacing such conditions and allowing accuracy in diagnosis and preventions.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Contact Lens Sensors

The lenses are placed in the angles between the cornea and the sclera known as the meridional angle. It is noninvasive and its location guarantees the lowest risks of injury to the eye as well inhabiting vision. It is also very progressive in terms of its design and implementations since lenses are used widely to correctly visual impairments. The lens sensors detect changes in the angle between the sclera and the cornea due to changes in the IOP. The principle behind this is the changes in the corneal curvature with changes that are affected by changes in the IOP pressure. A strain gauge is used to collect the changes and transfer them to a detecting mechanism. The gauge is placed in a whetstone bridge configuration. This brigade consists of two sensing resistive gauges and two compensation resistive gauges. The former offer double sensitivity while the latter is more attuned for thermal compensation. The sensing resistive gauges come with a crucial shape that is meant to offer the greatest pressure from IOP. The soft lens can deform, which allows detectable changes that can be detected and passed along to readers. Integrated into the lens is a microprocessor and an Application Specific Integrated Circuit (ASIC), which are used to control the wireless interaction of IOP measurement with an external receiver. The ASIC, which is embedded in the lens transmits a voltage that is directly proportional to the strain received from the lens. This is analogous to the changes in the IOP detected from the eye. These changes are transmitted to a portable device which is maintained and accessible to the patient.

B. On-Chip Sensor Device

They are implants that are embedded in the eye. They work internally with options changing based on their power demands as well as condition of the patient. They are less intrusive since a simple surgery is all that is needed to coordinate their operation. They measure pressure using similar mechanisms differing only in their reporting as well as power sources. The general mechanism is described below. The device contains a micromechanical pressure sensor which is arranged in an array. It also has a temperature sensor, an antenna, a calibration electronic, a digital control unit, and an RF transponder. The advance of micromachining has enabled the miniaturization of these components allowing them to be embedded in the system. The ASIC component of the device is made up of references, voltage regulators, a radio frequency rectifier, and a sensor. The measurement of IOP depends on tow capacitors. The first one is MEMS capacitors whose capacitance varies with change in IOP.

This varies the levels of charge and discharge of the MEMS device that allowing detectable changes. The other capacitance holds the base charge that is used for reference to the changes in the other capacitor. The differences in capacitance and charge time of these two capacitors allow for the generation of a pulse by the digital logic circuit. The time between the initial charge up and the threshold is proportionate to the capacitance of the MEMS and hence correlates to changes in the IOP. The pulse generated is transferred to a memory module in digital format. A nonvolatile Ferroelectric random access memory (FeRAM) is used to provide storage of the data. The antennae provide the transmission and recharging source through the RF module. This allows the sensor to act without internal power and gets t power from the stimulation of the RF signal. A variation of this module relies on solar power collected from light energy to the eye. This reduces the reliance of external source of energy and thus acts independently. The energy reaches the eye cornea and is collected by a 0.7mm2 solar cell. A thin film lithium battery is then used to store the energy and operate the implanted device.This device allows self-monitoring since it is embedded in the eye. The communication between the device and an external device further allows the patient to monitor changes in the IOP. This is significant since it allows a low running costs system of managing Glaucoma. The device can further transmit to an external device that amplifies the signal to coordinate and provide services to normal devices such as Smartphone. This is a key factor in developing countries since their acceptance of Smartphone technology has boosted numerous industries. The miniaturization of the devices is key in the delivery of this technology. Adaptation of the chip is in its partial intrusion and proper functioning in assessing the level of IOP of the patient. Therefore, it increases its acceptance rates in the areas of implementation and provides a good chance for further reduction of inhibiting conditions of glaucoma.

IV. CONCLUSION

In conclusion, these technologies are likely to translate into higher acceptance rates of the technology and thus provide a platform for tackling glaucoma. Self-monitoring allows the painless condition to be a transition to visible signals which can be interpreted correct and corrective measures taken. The leverage lies in the constant monitoring of the IOP and ease of reporting. It allows patients to take charge of the condition, which, unlike other conditions, has limited internal mechanisms in terms of pain or external discharge to prompt ophthalmological intervention. Most conditions prompts medical assistance and constant monitoring since they have limiting effects such as pain, nausea or other physical manifestations. This makes it inevitable for the patient to ignore the signs and medical assistance is immediately sought. However, IOP is insidious and is not preceded by any pain in the part of the patient. However, the condition is worsened the more it is ignored which may have permanent and lasting consequences such as blindness.

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