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Nano Tattoos as Biosensors for Medical Diagnostic Applications

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Abstract:

Nanotechnology is a new and innovative field that measures and manipulates material at the level of one to one hundred nanometers, each of which is one billionth of a meter. Combining this with biology, the physical sciences, and engineering opens an entire new realm of technology called nanomedicine. Although there are currently methods for treating those with diabetes, the approach of testing blood glucose levels and administering insulin injections are not completely effective. Although nanomedicine for diabetes is relatively new and testing is still being done, scientists and engineers must continue to devote time and resources to progress the development of glucose monitoring systems. With the use of nanotechnology, nanoparticles provide a means to measure glucose levels continuously instead of only at specific times. This is very important for diabetics; instead of checking their sugar levels only once or twice a day, they will have constant knowledge as to where their sugar levels are located. The smart tattoo can provide the solution to this ongoing problem. If smart tattoos become commercially available for insulin-dependent diabetics, it is vital that it is a safe and reliable means for glucose monitoring. In order for this to happen, engineers and scientists must undergo comprehensive research, along with a set of guidelines to abide by in order to ensure integrity and honesty. The current paper explores the feasibility of smart tattoos for future medical diagnosis purpose.

Keywords: NANOTECHNOLOGY, BIOSENSOR, NANOSENSOR, DIABETICS, NANOTATTOO

I. INTRODUCTION

Nanotechnology is a new and innovative field that measures and manipulates material at the level of one to one hundred nanometers, each of which is one billionth of a meter. Combining this with biology, the physical sciences, and engineering opens an entire new realm of technology called nanomedicine. The appeal of nanomedicine evolves from the fact that nanoparticles can effectively deliver drugs to cell and tissue sites where the drugs are effective [1]. There is much potential for nanomedicine, of which the most prominent is the nanotechnological approaches that are being developed to improve the quality of life for those with insulin-dependent diabetes.

Although there are currently methods for treating those with diabetes, the approach of testing blood glucose levels and administering insulin injections are not completely effective. Although nanomedicine for diabetes is relatively new and testing is still being done, scientists and engineers must continue to devote time and resources to progress the development of glucose monitoring systems.

Along with this, engineers need to be aware of the ethical implications that are part of nanomedicine. With the Engineering Code of Ethics as a guide, engineers can ensure that they are not infringing upon a patient's right to safety. Holding a true guide of conduct produces a high standard, that allows prospective engineers to follow. The importance of this, is that future engineers will know ethical approaches that need to be followed. The nanoparticle is made of 120 nanometers wide nanodroplets mixed with a fluorescent dye and sensor molecules that bind to certain special chemicals. The light used to produce the fluorescing property is made by adding a filter on to an i-Phone. This makes more number of molecules to get a stronger fluorescence. A photo of the fluorescence was taken with the i-Phone camera, and biomarker levels were calculated by analyzing it with a computer. Heather hopes to slowly design an i-Phone application that will be able to read the output.

If this technology is properly developed, there will be no more need of injecting syringes for drawing blood, and expensive tests. As tattoos are equally painful, the researchers are trying to divert the same technology into simple skin plants.

II. THE IMPORTANCE OF TREATING DIABETES

Diabetes is a disease that can be accompanied by dangerous complications if not monitored carefully. From my own personal experience, I witnessed my grandfather lose his leg below the knee due to complications of diabetes. This was caused from his inability to accurately determine his glucose levels at different points during the day. Due to his experience, I became intrigued by alternative forms to treat diabetes, such as nanotechnology. If my grandfather had better means of knowing his glucose levels at all points of the day, there would have been a possibility of preventing his amputation. However, my grandfather is not alone. Currently there are around twenty-four million people in the U.S.

who have diabetes [2]. This number could increase to 44.1 million by 2034, with treatment costs estimated around $336 billion [2]. From these statistics, it is obvious diabetes is a growing issue that affects people of all ages. In advancing alternative means of treating diabetes, countless lives will be improved.

There are two types of diabetes, each caused by several determining factors that predominantly affect different age groups. Type 1 diabetes affects children and young adults, and is caused by the body's inability to produce insulin [3], which is a hormone produced in the pancreas that regulates the amount of glucose in the blood. Type 2 diabetes results from when the body does not produce enough insulin, or the body cells ignore the insulin completely [3]. Therefore, the liver is unable to store the sugar in the fat cells in the form of glycogen [4], which the body uses for energy. However, in this paper, I will focus on the use of the smart tattoo in accordance with those with insulin dependent diabetes.

Currently, it is becoming more apparent that the traditional methods of determining blood glucose levels, are insufficient. An example would be the finger-prick capillaries, which can be painful, cannot be performed when the patient is sleeping, and most importantly, it can miss dangerous fluctuations in blood glucose concentrations between tests [5]. With the use of nanotechnology, nanoparticles provide a means to measure glucose levels continuously instead of only at specific times. This is very important for diabetics; instead of checking their sugar levels only once or twice a day, they will have constant knowledge as to where their sugar levels are located. The smart tattoo can provide the solution to this ongoing problem.

If smart tattoos become commercially available for insulin-dependent diabetics, it is vital that it is a safe and reliable means for glucose monitoring. In order for this to happen, engineers and scientists must undergo comprehensive research, along with a set of guidelines to abide by in order to ensure integrity and honesty. The National Society of Professional Engineers put forth a code of ethics that extensively outline the conduct that engineers follow. The most prominent guideline explains "engineers shall hold permanent the security, health, and welfare of the public"[8]. Especially in dealing with healthcare, engineers must ensure that exhaustive testing is completed before any of the technologies are available to the public. This code impacts how research is performed, in that they cannot falsify information or present deceptive results. Nanotechnology is still relatively new and with that, engineers are still unsure of the long term effects. There is an uncertainty if the technology will become harmful or have any adverse effects. Therefore, with this ethic in place, engineers will not put forth a product, in this case the smart tattoo, until a thorough understanding of how the technology performs over time is reached. Another code of ethics that engineers must abide by is that they "shall perform services only in their area of competence"[8]. Engineers will only involve themselves in assignments when qualified by education or experience in the specific technical field involved[8]. In the case with the development of the tattoo, the engineers will contribute only to the parts of their understanding. This reinforces the fact that when it comes to the biological side of the nanotechnology, engineers will not impose their ideas unless they have a thorough understanding of what process is taking place. This ideal impacted my reason for supporting the smart tattoo, since I believe it will guide engineers away from wasting time by making false assumptions of biological processes, and instead taking feedback from the biologists. “People are very sensitive,” Kugel says. “They can feel objects in the mouth that are 50 or 60 microns across”—about the thickness of a sheet of paper. “If it’s at all irritating to a patient, he or she will complain about it. You’d need to make sure it’s actually comfortable enough to leave in place for long periods of time.”

Future1. Biosensor Tattoos on the arm will help to know the Heart rate, Blood Pressure level, glucose level and the oxygen level of the patient.

III. SMART TATTOO: HOW IT WORKS

The approach of using nanotechnology as a way to provide continuous monitoring of blood glucose is the "smart tattoo." This tattoo is a means of measuring glucose through the skin, allowing for a less invasive approach as compared to conventional methods. "The tattoo contains nanospheres containing a covalently bound phenylboronic acid derivative as well as two attached fluorphores that have been synthesized" [2]. With the absence of sugar, the nanospheres are small, holding the fluorophores close, keeping the color of the tattoo. When sugar is present, it bonds to the bromic acid, increasing the size of the flurophores, and decreases the color of the tattoo. This alerts the diabetic when their sugar is low and insulin is needed. The nanomaterials and nanosensors that are part of the "smart tattoo" have significant advantages because of their small size. They have high surface area to volume ratios as well as enhanced optical properties that allow for the improvement of the accuracy and size of the sensors for treatment of diabetes [2].

IV. THE BENEFITS OF THE SMART TATTOO

It may seem that just taking one or two blood glucose readings from finger-prick capillaries are fairly sufficient, but the research exemplifies how readings are missed when not monitored continuously. For example, referencing the chart above, the data from uninterrupted monitoring indicated that a hypoglycemic event occurred between the first two data points [2]. If something like this occurs, it can result in deadly diabetic shock. With the exposure to continual readings, this will allow the patient to better prevent an event from happening, therefore avoiding complications. This can also prove to be advantageous by allowing the patient to better have knowledge of their blood glucose levels at any given point. With the continued development of sensors such as the "smart tattoo," it will truly enhance and simplify the lives of those with diabetes.

V. CURRENT PROGRESS IN WORK GLOBALLY ON NANO TATTOO

The following technologies are smart tattoos that bind to the skin and incorporate electronic devices to monitor the human body. Smart tattoos are thin, stretchy sensors worn on the skin much like a temporary tattoo. They combine the comfort of a flexible sensor with electronic components, providing a human-machine interface that allows for medical monitoring and even pathogen detection.

(a). University of Illinois[11]

Researchers at the University of Illinois have developed a temporary smart tattoo that allows for the monitoring of vital signs without the need for tape, conductive gel, electrodes or bulky wiring. Embedded in a film that is thinner than a human hair, these electronic sensors muse van der Waal force to allow the film to stick to skin without hindering motion, and are expected to stay on the wearer for up to two weeks. Currently, the sensors monitor temperature and heart rate, but scientist also believe these smart tattoos could also monitor brain wave, sense speech through the larynx, heat up to aid in wound healing, or even be designed to become touch sensitive , which could revolutionize the way in which artificial limbs are designed

(b). Northwestern University[12]

Northwestern University has designed a skin-mounted electronics with embedded circuitry in a flexible, bendable device. Discreetly worn and easily removed, the platform has been demonstrated with a wide variety of electronic components, including RF capacitors, solar power cells, transistors, LEDs, conductive coils and wireless antennas. Biomedical applications for these devices could include EEG and EMG, thermal sensors, blood oxygen sensors, and in situ EEG monitoring for understanding brain function outside of a laboratory. Through the use of electronic nanoribbons, the researcher conducted a speech reader experiment where they were able to able to differentiate between different vocabulary words, and control (with over 90 % accuracy) a voice-activated interface for a video game. This capability could revolutionize the way that patients with neurological or muscular disorders could interface with computer, and therefore the world around them.

(c). Nokia Vibrating Tattoos[13]

Nokia has employed the use of ferromagnetic ink directly into a smart tattoo capable of alerting the wearer of things such as incoming calls or environmental alerts. The device works by generating a magnetic field that upon activating the ferromagnetic ink, produces perceivable and distinguishable vibration pattern in response to a signal (be it a text, voicemail or incoming call) that allows the wearer to differentiate between incoming messages.

(d). MC10's Biostamp[14]

MC10's Biostamp prototype is a flexible, wearable computing device that provides a collection of sensors that can be applied to the skin in the same way as a temporary tattoo. Using near field communication (a wireless technology such as that used in E-Zpass) the sensors in the device collect data such as heart rate, brain activity, temperature and UV exposure while sending the data to a smartphone for further analysis. The Biostamp could be worn for about two weeks, providing full- time medical monitoring, a capability that could forever change the way in which medical diagnosis are made.

(e). Elecctrozyme's smart tattoo[15]

Electrozyme's electrochemical biosensor tattoo was originally developed by researchers at the Laboratory for Nanobioelectronics at UCSD. The printed sensor analyses in real-time chemical elements in the wearer's sweat and evaluates things such as lactate buildup to quantify muscular exertion, electrolyte balance, and even epidermal pH to assess hydration levels. Proprietary algorithms recognize and integrate physiology patterns from the sensors in real time. In addition to their biosensors, Electrozyme is also developing an epidermal biofuel cell that they hope will power their wearable sensor by capturing the biochemical fuels found in sweat.

(f). Princeton and Tufts University[16]

Princeton and Tufts University scientist are developing an electronic wireless tooth tattoo designed to measure bacterial levels in the mouth in order to help in the detection of gum disease. The sensor, made of silk, graphite and gold, is much less invasive than drawing blood and promises to one day detect more than just periodontal disease by assessing other indicators of disease that may also be measure from saliva. The scientists are looking increase the specificity of the sensor by constructing peptides that have the ability to bind with specific strains of bacteria.

(g).University of Illinois at Urbana-Champaign/ ShenXu[17]

Dr. Xu and his colleagues at University of Illinois are experimenting with controlled mechanicalbuckling, soft microfluidics, and structured adhesive surfaces to develop skin-mounted power supplies, circuits, sensors and radios geared towards the development of wireless, clinical grade physiological monitoring.

VI. CONCLUSIONS

Research and development of nanosensors for the management of diabetes is an important research area and will remain so in the future. Even though progress in this field is rapid, the ultimate goal of achieving long-term, accurate, and continuous glucose monitoring in patients has not been reached. In order to help achieve this goal, future work should emphasize testing in realistic, clinical samples even for proof of concept sensor designs. These sensors should also be compared more thoroughly with commercially available sensors to better demonstrate the advantages or disadvantages of the nanosensors. These direct comparisons should help to justify the additional cost and effort to overcome manufacturing challenges associated with nanosensors compared with standard sensors. The cost and effort of large-scale manufacture of new sensor approaches must provide either extreme improvements in accuracy with minimal additional new cost or an improvement in patient quality of life. This is a large problem to overcome for the approaches that incorporate nanomaterials into electrochemical detection approaches or detect glucose through direct oxidation, as the patient must still undergo the same sampling methods (finger-stick), yielding no improvement in quality of life. In order to have an impact on diabetes, these sensors must demonstrate extremely high improvements in response, as cost is unlikely to decrease below current manufacturing approaches. In addition to cost, other questions remain about the ability for these approaches to impact clinical care, including biocompatibility and sensor lifetime; these questions must be answered through further research in order for patients to benefit from this technology.

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