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Nano sensors integrated into dental implants for detection of acute myocardial infarction

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Abstract: ***Despite dramatic improvements in diagnosis and therapy cardiovascular disease (CVD is still the leading cause of death in the world. Millions are spent on cardiac care therapeutics each year.The prevention of all forms of cardiovascular disease is the active field of biomedical research with hundreds of scientific studies being held in the field. Many heart attack victims experience non-specific symptoms and secure medical help too late after permanent damage to the cardiac tissue has occurred. Because of non-specific symptoms some heart attack victims even do not know that they have experienced the heart attack and do not ask for medical help that is tremendously dangerous for their health.This article is dedicated to the new RFID device that can implement immediate diagnosis of cardiac disease as soon as it starts or even earlier.***

Keywords: RFID-technology, health care, nano sensors, biomedical sensors, microelectronics, health monitoring devices

1. INTRODUCTION

Cardiovascular disease is the leading cause of death in the developed countries. Millions of people are dying every year because of cardiovascular diseases.

The most common type of cardiovascular diseases is myocardial infarction. Myocardial infarction (MI) or acute myocardial infarction (AMI), commonly known as a heart attack occurs when the blood supply to part of the heart is interrupted. This is in most cases due to occlusion (blockage) of a coronary artery following the rupture of a vulnerable atherosclerotic plaque which is an unstable collection of lipids (like cholesterol) and white blood cells (especially macrophages) in the wall of an artery. The resulting ischemia (restriction in blood supply) and oxygen shortage, if left untreated for a sufficient period, can cause damage and/or death (infarction) of heart muscle tissue (myocardium).

Classical symptoms of acute myocardial infarction include sudden chest pain (typically radiating to the left arm or left side of the neck), shortness of breath, nausea, vomiting, palpitations, sweating, and anxiety (often described as a sense of impending doom). Women may experience fewer typical symptoms than men, most commonly shortness of breath, weakness, a feeling of indigestion, and fatigue [1], [2].

Approximately one quarter of all myocardial infarctions is silent without chest pain or other symptoms. A heart attack is a medical emergency, and people experiencing chest pain are advised to alert their emergency medical services because prompt treatment is beneficial.

The problem is that after silent myocardial infarctions people do not alert their emergency medical services as they do not know that they have experienced heart attack.

Myocardial infarctions are also very dangerous even if they are not silent. For example shortness of breath while driving can cause tremendous troubles on the road involving car crashes.

Immediate treatment for suspected acute myocardial infarction includes oxygen, aspirin, and sublingual glyceryl trinitrate (colloquially referred to as nitroglycerin and abbreviated as NTG or GTN). Pain relief is also often given, classically morphine sulfate [3].

Sometimes people having heart attack cannot identify classical symptoms and without knowing about heart attack have the wrong immediate treatment.

The diagnosis of myocardial infarction is made by integrating the history of the presenting illness and physical examination with electrocardiogram findings and cardiac markers (blood tests for heart muscle cell damage) [4].

A chest radiograph and routine blood tests may indicate complications or precipitating causes and are often performed upon arrival to an emergency department. So these ways of diagnosis are not effective enough.

There is certainly a strong need for more effective early diagnosis of cardiac diseases.

Furthermore, the relevant instruments designed to perform such measurements are mostly restricted to a laboratory-type of testing and are not amenable for the

relevant to heart attack settings such as the in the emergency room or the ambulance.

This article presents the device that proves to significantly increase the detection of acute myocardial infarction. The main novelty is the great mobility of the proposed diagnosis system and its size that significantly improves the process of the modern diagnosis methods.

2. THE SYSTEM ARCHITECTURE

2.1 Basic concept

Over the past 20-30 years numerous research studies have validated the use of saliva as an analysis medium to measure the fraction of proteins in the blood stream. During researches all over the world and particularly in Russia a list of special cardiac biomarkers was compiled. These cardiac biomarkers present in a saliva sample of a person currently having a heart attack or in close danger of heart attack. Advantages of saliva analysis to all other diagnosis of cardiac diseases are obvious.

The saliva analysis is noninvasive, simple, safe, stress free, and painless. The described method is already successfully used in developments of Texas University team which used saliva analysis in developing of cardiac sensor.

The mechanism of saliva analysis to determine the close heart attack is basic for the described device. Our research group developed the smallest possible saliva sensor device programmed to detect special cardiac biomarkers in saliva.

The main idea is to build this saliva sensor into a dental implant that is always in the mouth of a patient with the heart attack risk.

The particular thing about this saliva sensor is that it is integrated with RFID chip.

RFID (Radio Frequency Identification) is the way of data transmission from a tag to a reader using radio-frequency electromagnetic fields [5].

The whole construction is packed in protected resin that protects the tag from food and saliva. Saliva sensor gets access to saliva only on demand through small pipes. An RFID basic system consists of two main components: RFID tags and RFID readers [6], [7].

RFID tag is a small device with a variety of possible appearances from stickers to small grains embedded in official documents. In our case RFID tag looks like a device small enough to fit into a tooth.

A tag basically consists of a microchip and a metal coil, which acts as an antenna. In some cases, it can also contain a battery and some other microchips intended for increasing its computational power. In our case RFID tag contains long live battery and the microchip that not only controls the tag memory access but also is used to perform saliva analyses.

The second component is RFID reader. RFID readers are active devices used to read the information stored in tags. In a nutshell, readers emit a radio wave so that all tags in their range answer by broadcasting their embedded information (i.e. a set of bits). In our case RFID reader is implemented as wristband with built in microprocessor. The wristband is used to make the alarm signal in case of a close heart attack.

2.2 RFID reader

Microchip in RFID tag stores the result of the previous saliva analysis. The results are stored in memory equal to 256 bit. Each bit encodes the presence of at least one cardiac biomarker. Currently only 26 reactions are implemented but in future the number of such reactions can increase. 1 stands for positive reaction on the particular cardiac biomarker and 0 stands for negative reaction.

The RFID reader occasionally interrogates the microchip and analyses whether the results can be regarded as the symptom of a close heart attack. In case the result is positive or suspicious enough the wristband informs the person on the high risk of heart attack. The decision on alarm signal is made by microchip embedded in RFID reader.

The same microchip stores information on the RFID tag battery charge, and the amount of tests left before the analyses cartridge change. Currently the cartridge can work a month without a charge that seems to be a quiet long period.

The wristband also stores the patient information like personal data and special treatments recommended. In case of heart attack the instructions can be shown on the LED display and can be useful both for the patient and for the helpers if the patient is unconscious.

The wristband also has remote control function to ask the saliva sensor for immediate analysis in case of suspicion.

The wristband also has integrated GPS to enable hospitals to instantly locate anguished patients and their condition.

2.3 RFID tag with integrated saliva sensor

RFID tag consists of a long live battery, metal coil, which acts as an antenna, microchip which stores information and controls the saliva analysis and saliva sensor which performs the analyses.

The protected resin with RFID tag is installed in a dental implant.

A dental implant is an artificial tooth root replacement and is used in prosthetic dentistry to support restorations that resemble a tooth or group of teeth. A typical implant consists of a titanium screw (resembling a tooth root) with a roughened or smooth surface. There are no absolute contraindications to implant dentistry

As the implantation is not always the best solution for every patient it is possible to install the saliva sensor with the help of dental bridge.

Dental bridge work usually involves the creation of a false tooth to replace a missing tooth. In our case the similar technique is used. The metal loops are attached to the supporting teeth and hold the resin with saliva sensor. It is not necessary to have two supporting teeth as it is possible to use the cantilever dental bridge technique when the resin is designed to be anchored on only one tooth. Before performing the bridge work, the dentist can help the patient choose the right tooth colour for the bridge. The best colour is what looks the most natural for the patient based on natural tooth colour, skin tone and eye colour. It is also possible to fix the resin with saliva sensor behind the teeth so that it cannot be observed.

The dental work of this kind is rather easy if the patient already has dental implants or dental bridges. This way the current implant can be rather fast replaced with the resin saliva sensor.

Saliva sensor integrated to RFID chip detects special cardiac biomarkers in saliva using the correspondent chemical reactions. Reaction for each cardiac biomarker undergoes in individual cell in saliva sensor like shown in Fig. 1.

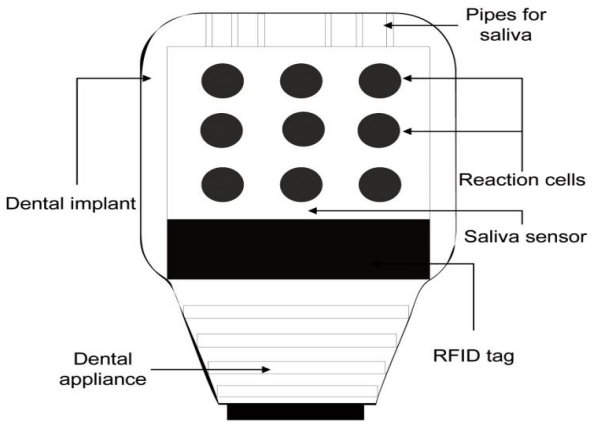

Figure 1 Dental implant with saliva sensor and RFID tag inside

Once a month the cartridge inside the dental implant must be recharged with new chemicals to perform analysis. The patient can ask the nearest dentist to replace the implant with the new charged once. The group is now working on developing the cartridge that can operate longer without recharge. The saliva sensor now performs several reactions to test the presence of the most obvious cardiac biomarkers. In future the number of reactions will increase and the accuracy of the test will be much more as well.

3. CONCLUSION

Although this invention can be difficult to be used this time as there are some features to be significantly improved, it will be a serious choice in the near future. Overall, the system promises to significantly improve the accuracy and speed of cardiac diagnosis.

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