Early detection of Myocardial Infarction: Biomarkers and Devices

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Abstract *– Increased mortality from myocardial infarction in India is majorly caused by delayed or inadequate early diagnosis. Widely used biomarkers like cardiac troponin, cardiac natriuretic peptides, and their combinations are good early indicators of acute myocardial infarction(AMI). Utilizing colorimetric techniques, quantum dot-based biosensors, CMOS-compatible sensors, nanowire arrays, etc., it has become possible to detect these biomarkers. ECG, heart sounds, heart rate, and skeletal postures are the main metrics used by sensing devices to identify abnormalities in heart function. For the early identification of AMI, a variety of devices have been conceived and developed, including wearable devices, microfluidic paper-based devices (PAD), IoT devices, Kinect-based systems, smart steering wheels, and smartphones. In this review paper, we will first analyze the biomarkers and relevant parameters which are widely used in the detection and diagnosis of myocardial infarction along with biosensors that aid in the process. We then provide a literature review on the existing devices.*

Keywords: *Biomarkers, Biosensors, Devices, Early diagnosis, ECG, Myocardial infarction.*

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1 INTRODUCTION

Acute myocardial infarction is a prevalent condition that has a significant impact on mortality, morbidity, and societal costs ("Acute Myocardial Infarction" n.d.). About 25% of all fatalities in India are attributable to heart attacks. This occurs as a result of delayed or inadequate early diagnosis of the symptoms (Chandurkar et al. 2018). Therefore, for the early diagnosis of myocardial infarction, we have to first analyze the biomarkers which will help us to do so.

2 PREVALENT BIOMARKERS USED

The optimal biomarker for identifying myocardial injury must be expressed at relatively high levels inside cardiac tissue, have high clinical sensitivity and specificity, and be readily identifiable in the blood shortly after the onset of symptoms like chest discomfort (Wang et al. 2020). Cardiac troponin and creatine kinase-MB isoform are two well-known biomarkers used to diagnose acute myocardial infarction ("Biomarkers in Acute Myocardial Infarction" n.d.). Other than these biomarkers, markers like natriuretic peptides (BNP and NT-proBNP), are also used. Cardiac troponin I (cTnI) and cardiac troponin T (cTnT), two of the isoforms, are the most specific markers for acute coronary syndromes and are regarded as the "gold standard" in the diagnosis of AMI because of their elevated levels, which have increasingly become a sign of acute myocardial infarction (AMI) (Wang et al. 2020). Heart failure assessment recently includes measuring cardiac natriuretic peptides in plasma as a diagnostic tool (Curry 2005). There are other choices like combining high-sensitivity cardiac troponin and B-type natriuretic peptide in the detection of inducible myocardial ischemia but it is found that this kind of dual biomarkers does not promote the diagnostic accuracy of inducible cardiac ischemia (Puelacher et al. 2018).

The predictive performance for prediction was significantly better if copeptin was included (C-index of 0.80) compared with that of troponin alone (C-index 0.78, $p = 0.01$ for the added value of copeptin to troponin I) (Afzali et al. 2013).

To detect such cardiac biomarkers, various biosensors are used. Most efficient biosensors include a Human Cardiac Troponin I Detection by a Quantum Dot-Based Biosensor Using a Liquid-Core Waveguide. Fluorescence resonance energy transfer (FRET), a chemical signal transduction technique between two fluorescent molecules known as the donor and acceptor, is used in the biosensor architecture. The antibody-antigen binding event starts a conformational shift inside the structure of the antibody when it is exposed to the Troponin I antigen. The distance between the donor and acceptor varies as a result of this morphological change in the antibody, causing a discernible shift in energy transfer. To further improve the performance of the biosensor system in this study, quantum dots were used as the FRET donors and organic dyes as the acceptors. To get highly sensitive and precise measurements, this sensing mechanism was subsequently integrated into a liquid-core waveguide (LCW) device that could capture the resultant fluorescence(Cody Stringer, Hoehn, and Grant 2008). CMOS-compatible, label-free silicon-nanowire biosensors to detect cardiac troponin 1 is also another prominent method used. Using silicon nanowire (SiNW) based field-effect transistors, a label-free biosensor for electrical detection of cardiac troponin I (cTnI), a highly sensitive and selective biomarker of acute myocardial infarction (AMI), is developed (FETs)(Kong et al. 2012). Colorimetric detection of cardiac troponin I is done using PDMS gold nanoparticle composite film-based silver. Other ways to detect cardiac biomarkers are done by employing nanowire arrays using readout ASIC. An array of silicon nanowire sensors and an interface readout application-specific integrated circuit make up the label-free detecting system (ASIC). Direct simultaneous-multiplexed detection of cardiac biomarkers in serum is made possible by this method, which offers a quick and highly sensitive solution(Zhang et al. 2012).

3 EXISTING DEVICES USED FOR THE EARLY DETECTION OF MYOCARDIAL INFARCTION

Despite the vital biomarkers presented above and the biosensors used for its detection, baseline parameters like ECG, heart sounds, heart rate, skeletal posture, etc are widely used. The automated diagnosis of acute myocardial infarction (AMI) using electrocardiogram (ECG) recordings is the subject of an expanding body of research. Several techniques rely on variations between the baseline (without AMI) and AMI condition ECG(Aranda Hernandez et al. 2023). Many devices utilize ECG for the diagnosis of MI. A very noticeable one includes the ECGalert: A Heart Attack Alerting System. The patient's smartphone is used to install an application that takes ECG signals from the sensor, and sends them to the data center, which processes them, and determines whether there is any aberrant heart activity. This procedure requires attaching a small portable wireless ECG biosensor to the patient's body. The system is also linked to a cloud-based web application. ECGalert is a cloud-based heart attack alerting system that connects physicians in charge of offering around-the-clock remote medical care(Gusev, Stojmenski, and Guseva 2017). Heart sounds are used as a parameter in devices to detect heart attacks like in the case of the device which uses heart sound recording via smartphones to detect anomalies. The database will save the default values for normal and pathological heart sounds as "Lub dub" and "murmur," respectively. The recorded sound will automatically be compared with the database of previously stored audio. For this technique, a mobile microphone must be placed on the left heartbeat (Ashrafuzzaman et al. 2013). Other devices include heartbeat sensors and pressure sensors to detect abnormal heartbeat levels. This IoT device consists of LED light and buzzer constructed on ATmega 328 and a wifi module that alerts the user by turning on the LED light and buzzing when the heartbeat level of the patient does not fall within the normal heartbeat level set(N. Patel 2018). Detection devices have also been used in the automobile sector. For example, Heart-Attack Detection Steering Wheel is employed in vehicles. The created device noninvasively measures the driver's skin resistance, body temperature, and heart rate continually. While the driver is being questioned about his or her current physical status via an interactive system, the driver confirms the qualitative symptoms of lightheadedness, nausea, weariness, chest discomfort, and numbness in the left hand. The driver is prompted by a clever algorithm to park the car on the shoulder of the road whenever the onset of myocardial infarction is identified, and the gadget automatically completes the following tasks within 30 seconds: i) send an SMS to the paramedics with the driver's current location; ii) notifies other drivers nearby that there is a medical emergency on board; and, iii) delivers a vasodilator pill to the driver from a built-in container. The purpose of this procedure is to preserve the driver's life while enhancing traffic safety(Abu-Faraj et al. 2018). Not only in steering wheels but these sensing devices are incorporated into wearable devices as well. The introduction of wearable technology enables long-term patient monitoring in ambulatory settings. Designing ultra-low energy wearable devices for long-term patient vital sign monitoring is one of the key difficulties in this field. To solve the issue mentioned above, a real-time event-driven classification method based on support vector machines (SVM) and statistical outlier identification can be used. This method's key objective is to keep the classification algorithm's complexity low while maintaining a high level of classification accuracy(Sopic et al. 2017). Gaming devices like Kinect which has been majorly used in the medical field for rehabilitation purposes can also be used for detecting heart attacks. Kinect tracks the human body and joints in the form of a skeleton. Heart rate is tracked by Microsoft's Kinect sensor using variations in skin tone. The updated Kinect camera can detect minute variations in skin tone caused by blood flowing through a person's body. The camera can calculate how many beats per minute the heart needs to beat to attain the blood's pace once it is known. Anomalies in heart rate can be found in this method. The technology allows for the pre-definition of the skeleton's position for chest pain. A heart attack can be diagnosed if this posture is observed together with a reduction in heart rate (S. Patel and Chauhan n.d.).

Other than these above-mentioned devices which utilize certain parameters like heart rate, and ECG signals to detect heart attack, many devices use cardiac biomarkers mentioned under the biomarker subheading for early detection and diagnosis. One such device uses a biosensor that is placed under a person's skin to monitor blood flow. It is advised that it be placed inside an artery. This sensor is used to determine the blood's troponin content. The Wireless Body Network Controller (BNC) attached RF device processes and transmits the data from the sensor and sends it to the medical monitoring system(Mamoon 2013). To simultaneously detect multiple cardiac biomarkers for the early and late diagnosis of AMI, a rapid microfluidic paper-based device (μPAD) was developed. With only a phone camera and/or desktop scanner available for quantification, an inexpensive and disposable "PAD" was created for simultaneous colorimetric determination of multiplex cardiac markers. This significantly reduced the analysis time (10 minutes) and decreased the cost of multiple marker measurement. The glycogen phosphorylase isoenzyme BB (GPBB) was detected during early (within the first 4 h) ischemic myocardial injury. GPBB is released in the blood circulation within the first 4 h after chest pain onset before myoglobin, CK-MB, and troponins(Lim et al. 2019).

4 CONCLUSION

Delayed or Inadequate early diagnosis of Myocardial Infarction leads to increased fatalities in India. Cardiac troponin, Cardiac natriuretic peptides, and their combinations are widely utilized as biomarkers that are excellent early indicators of acute myocardial infarction (AMI). Detecting these biomarkers has been carried out by using colorimetric mechanisms, quantum dot-based biosensors, CMOS-compatible sensors, nanowire arrays, etc. Developed sensing devices use ECG, heart sounds, heart rate, and skeletal postures as primary parameters to detect anomalies in heart functioning. Smartphone alerting systems, IoT devices, Kinect-based systems, Smart steering wheels, wearable devices, and microfluidic paper-based devices (μPAD) are designed and developed for the early detection of AMI.

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