CardioConnect

INTRODUCTION

Dominating mortality statistics at a global level, cardiovascular diseases have caused the estimated deaths of around 56 million people each year, and as of April 2023 approximately 7.6 million people in the UK are currently living with heart disease [1].
An insufficient supply of blood or oxygen to the brain damages neurones and brain tissue developing organ malfunction. This may potentially lead to an ischaemic stroke, vascular dementia, etc. overall increasing annual deaths associated with neurological diseases by 39%. [2]

OUR SOLUTION

We aim to improve the efficiency of patient waiting-list backlogs, prophylactic medicine and outpatient monitoring to reduce cardiovascular and neurological mortality statistics. Our innovation, **CardioConnect**, is a smart patch placed on the underside of the arm, beside the brachial artery, that uses a combination of photoplethysmography to measure heart rate and blood pressure; lipid panel testing in the form of replaceable cartridges which estimates blood LDL, HDL cholesterol and triglycerides levels; and blood glucose monitoring via a small glucose-sensing electrode inserted under the skin. The information is then recorded into our digital, AI-based system to assess the severity of the patients conditions wherein those suffering severe conditions are flagged to their local GP or hospital to reduce the need for patient consultations - ensuring a more optimal and economical form of communication.

WHY THIS SOLUTION?

We chose a simple and sleek patch to improve the holistic care of patients outside hospitals while also minimising disruption to their daily lives. The patch is minimally invasive with only the glucose sensor penetrating the skin. The simplification of the patch makes for 'at home monitoring' and remote cardiac regulation which considerably reduces the workload for experienced doctors, allowing them to focus on higher priority tasks. Our integrated AI and algorithm will regularly ask a series of questions e.g Does the patient experience any pain? Is the patient passing urine?
We intend for the patch to detect signs and precursors of strokes and heart attacks using the transmitted data to enable doctors to provide immediate care before the circumstances develop; also easing the burden on the NHS.

How is BLOOD PRESSURE & HEART RATE measured?

Photoplethysmography (PPG) systems utilise LEDs that emit light at specific wavelengths (ie. infrared light around 940 nm). The light from the LED penetrates the tissue and interacts with the blood vessels where some light is absorbed by the haemoglobin. A photodetector (PD) is placed adjacent to the light source where this transmittance is measured then converted into an electrical signal.

The blood vessels in the tissue expand and contract with each heartbeat, causing changes in blood volume.
During systole (contraction), the blood volume in the arteries increase, leading to increased absorption or reflection of light and in diastole, blood volume decreases - synonymously decreasing light absorption and reflection.

These changes in blood volume create a pulsatile waveform. The photodetector captures the variations in light intensity caused by the pulsatile blood flow. The acquired PPG signal undergoes various processing steps to extract relevant information. These steps may include baseline removal, noise filtering, amplification, and digitisation. The processed signal is then analysed to derive physiological parameters.

CONTEXT - ESTIMATING BLOOD PRESSURE

Heart rate is typically derived from the PPG signal by identifying the time intervals between successive peaks or troughs in the waveform. These peaks or troughs correspond to each heartbeat, and the time intervals between them are used to calculate heart rate.
PPG can provide insights into changes in blood volume, which are represented by the amplitude of the pulsatile component in the waveform. Changes in blood volume can be influenced by factors such as cardiac output, vascular tone, and peripheral resistance.

Machine learning techniques can be applied to PPG data to develop models that relate the PPG waveform features to blood pressure measurements. These models are trained using a dataset of PPG and corresponding blood pressure measurements. PPG can also be used to assess vascular health, peripheral perfusion, and other physiological parameters.

How are BLOOD GLUCOSE levels measured?

Similar to already existing glucose monitors, we have implemented flash glucose monitoring into the patch, using a small, flexible, electro-enzymatic sensor that can detect glucose concentrations in the blood.
Three main components: the **sensor** (made from a combination of flexible, biocompatible metal alloys, i.e., platinum-iridium with a polyimide insulation coating); a waterproof **transmitter** that sends signals every ten minutes and attaches to the sensor with a polycarbonate body; and an app **monitor** that records the glucose readings in real time.
A coating of glucose oxidase enzymes surrounds the electrode, breaking down the glucose in the patient's tissue fluid to produce hydrogen peroxide, which reacts with the sensor. This causes a potential difference, generating an electrical current proportional to blood glucose levels. Once transmitted into the smart device, the data is processed by our system's algorithm, which records and personalises the varying glucose parameters for specific patients in order to produce a valid glucose measurement.

How do we attain a CHOLESTEROL count?

Recommended Cholesterol Levels

Desireable	<200 mg/dl
Borderline High	200-139mg/dl
High	>240mg/dl

A small needle built into the patch can be mechanically pushed out - slightly to prick out a sample of the patient's blood. The sample goes through an enzymatic assay process, where specific enzymes cause a change or hydrolysis of the lipid contents of cholesterol to produce a measurable colour change within the blood.

This colour change is then quantified using optical sensors to determine the differing concentrations of LDL, HDL cholesterol and triglycerides in the blood.

The device monitors cardiac activity and is placed on the underside of the arm

Another device with the CardioConnect app receives a signal from the cardiac activity monitor

The app is connected to a cloud server in which the doctor also has access to the data.

The readings are ranked in terms of severity and extreme readings are also flagged.

The doctor can then go about the next appropriate course of treatment in a more time efficient manner.

Therefore, any concerns are diminished and diagnostic procedures can occur much more efficiently.

HOW the APP CardioConnect LINKS to the server.

You can download the app **CardioConnect** on your Smart Device, which will link to the patch where the data is transmitted for computational decoding and data analysis. This connection is done via a Bluetooth or NFC connection. The person should **hover** their device over the sensor until the app has been **updated** with the data from the sensor. A successful connection would be indicated by a **beep and a vibration** so the patient knows a connection has been established. Assuming the patient has a stable connection to the internet, all data is safely stored on an **encrypted cloud** to allow for the Doctors to access data (the encryption allows for all the data to be secure). As the data is stored on a cloud, it also means the patient can access data from previous sessions of recordings. Hence, less local storage on the patient's device is not used, meaning more storage can be used for other means revolving the patient.

HOW IT WORKS

Every few minutes, the sensor will measure glucose, cholesterol, pressure and heat rate and these will be sent to the app on your phone. On the app, there will be a more in-depth check, where an Ai will use the data received from the sensors and ask general questions to the patient (e.g are you feeling lightheaded?) to assess the severity. These questions will work alongside patient information such as weight, height and age, this will in turn help with the Ai's decision by comparing average measurements with the same characteristics as the person being tested. It will then ask if the person has specific conditions that may affect the results, such as obesity, diabetes and kidney disease. It will then ask if a person has specific symptoms, such as chest pain, a spreading pain from shoulders, arm, back, neck, or heartburn. The AI will corroborate all the answers and place them on a scale of 1-10, 10 being most severe. If the AI detects something highly abnormal such as levels of cholesterol reach 8-10 severity, then the patients GP will be notified and sent all answers to questions and necessary information, thus reducing time for the Doctor and ensuring that they see patients who need treatment the most and save time on patients who may not need a consultation. If a patient is highly severe their information and location (if prior to this patient gives location permissions) then nearby emergency responders can be alerted if the system believes they may experience something severe such as a stroke or heart attack.

Body	Sensor	Signal	Model	Output

CREATION of the SYSTEMS

Regarding the creation, we will need to amass large quantities of user-data. After a period of calibration, anomalies can be identified and removed, averages can be calculated and the data can be inputed to the system. An Ai algorithm can be made by modifying existing models such as GPT-4 and automating them to cross-reference an ill patient's data with that of a standard healthy person with similar parameters to detect any abnormalities.

Normal Rhythm
60-100 bpm. Normal, evenly-spaced complexes.

Arrhythmia
Normal complexes but irregular rhythm.

Bradycardia
Rate: <60 bpm. Normal, evenly-spaced complexes.

Tachycardia
Rate >100 bpm. Normal, evenly-spaced complexes.

Atrial Fibrillation
Irregular Ventricular response.

Ventricular Fibrillation
Wide rapid, irregular Ventricular complexes.

LIMITATIONS of PATCH

The PPG component that measures the heart beat and blood pressure can affect the overall data analysis as a result of motion and muscle contraction. To resolve this, our algorithm will have to implement machine-based learning to learn how to filter these factors out.
PPG is also sensitive to different skin pigmentations as darker skin tones have less light transmission, so the optical sensors will have to be fitted with multiples different wavelengths of light to help adapt to different skin tones and allow for better signal detection.
Patients on medications such as statins and fibrates can affect lipid levels which could mislead results in the lipid panel tests so the patient will have to input any other existing medications they take into the app and the Ai will adjust its severity measurements according to those medications.
The patch itself may cause skin irritation due to its adhesives, so the nurses or doctors must properly wash and dry the area before applying the patch and must rotate areas of patch placement.

FEASIBILITY

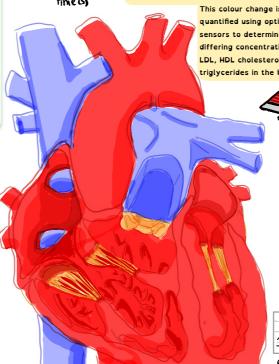The patch uses adapted existing technology to best serve the NHS plan for holistic care within cardiovascular and neurological care. The opportunity cost for the research, development and production will be offset by the savings made by the NHS in preventing cases of stroke and heart attacks in patients.
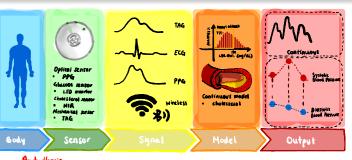
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References: