Mini-Project

Group 8

Contents

Background: blood flow

Coronary arteries deliver blood to the heart muscle, supplying it with oxygen and nutrients.

Coronary veins bring deoxygenated blood away from the heart.

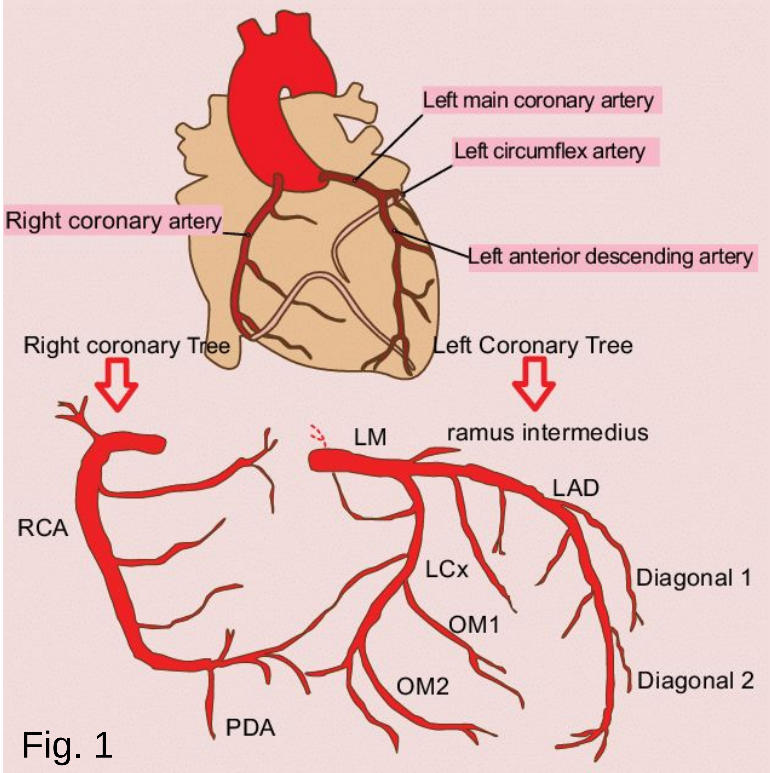


Fig. 1

Background: heart attacks - causes

Heart attacks (Myocardial Infarctions) are caused when there is reduced or blocked arterial blood flow to the heart muscles, known as myocardium.

As a result, the heart muscle becomes starved of nutrients and oxygen, which causes cell death, damaging part of the heart muscle.

This can happen due to Coronary Artery Disease, a blood clot, or a sudden spasm in a coronary artery. (1.1)

Background: heart attacks - causes

Coronary Artery Disease

- Most common cause of heart attacks
- Atherosclerosis, the buildup of plaque (fatty deposits containing cholesterol) in the coronary arteries, causes a partial or complete blockage, restricting the flow of blood to the heart muscle. (1.1)

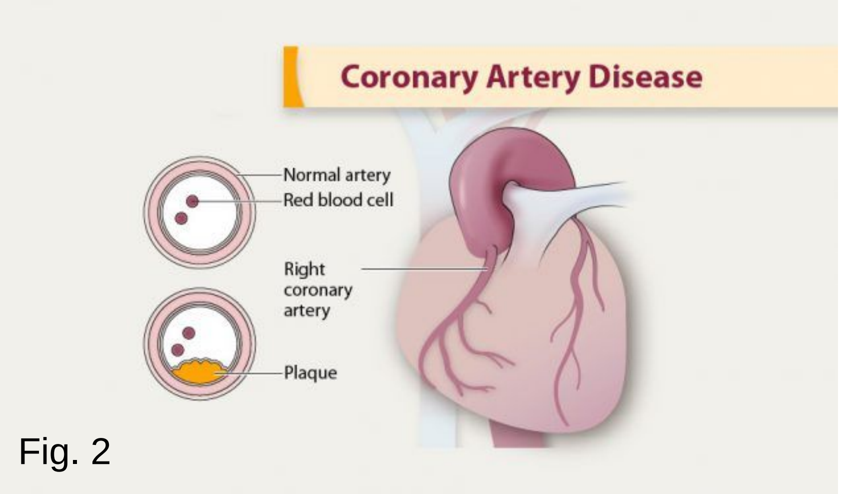


Fig. 2

Background: heart attacks - causes

Blood clot

- If a plaque that has built up due to atherosclerosis ruptures, the blood clot that forms at the rupture site can occlude the artery, blocking blood flow to the myocardium. (1.1)

Background: heart attacks - causes

Spasm of a coronary artery

- Uncommon
- Can be caused by the use of drugs such as cocaine, or by tobacco use
- Briefly prevents or shuts down blood flow to the heart

Background: heart attacks - risk factors (1.1)

- Age/Gender (men 45+, women 55+)
- Family history of heart attacks
- High blood pressure
- High levels of LDLs (low-density lipoproteins) / “bad cholesterol”
- Diabetes
- Genetic or autoimmune conditions (i.e. rheumatoid arthritis, lupus)
- History of preeclampsia (A condition causing high blood pressure during pregnancy)
- High triglyceride levels
- Obesity
- Lack of physical activity
- Frequent use of tobacco or illicit drugs, like cocaine

Where is the best placement of a sensor that measures blood flow?

For our project, it is crucial that the sensor acts over a large area and is close to the heart, so that it is able to constantly and accurately monitor changes in blood flow in each of the main coronary arteries.

The Left Anterior Descending (LAD) artery is especially important; because if blocked, it affect the key left ventricular function, leading to a “widowmaker” heart attack, which has a very low survival rate.

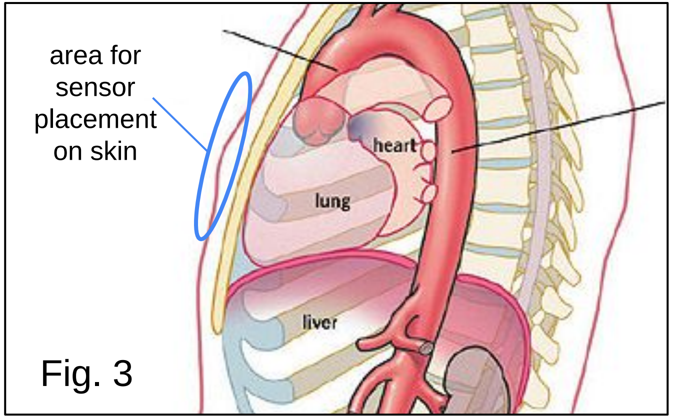


Fig. 3

Ideally, the sensor should be placed on the chest, anterior to the position of the heart, as shown above in *Fig. 3.*

The Device and its Elements

Wearable Sensor requirements:

- Adheres to human skin (and hair)
- Big enough to integrate all functional parts
- Able to detect and transmit signals
- Flexible and durable
- Biocompatible with our skin
- Non-invasive (2.1)

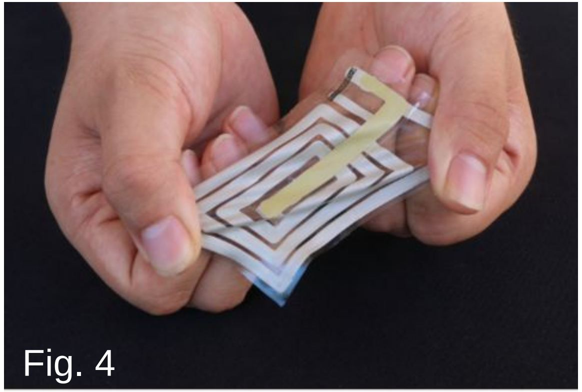


Fig. 4

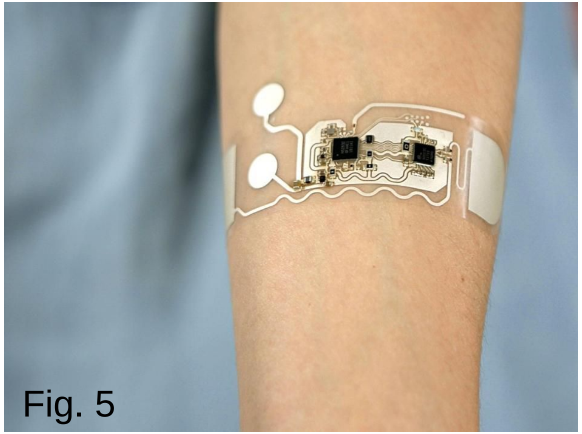


Fig. 5

What material should the sensor be made of?

- Material must be highly sensitive to subtle changes in our physiological index
- Material should be able to transmit the slightest signals accurately and precisely
- Material must have adhesive properties and be biocompatible
    - Also need to consider ability to stick despite bodily oil and sweat (2.2)
- Flexible electronic components that detects and transmits signals for data and monitoring (such as graphene)
- A thin and flexible film of polymer that protects the electronic components (such as plastic)

What material should the sensor be made of?

The material must also be biocompatible, therefore it must:

- Not cause damage to human skin cells
- Be safe and suitable for hair follicles and pores
- Allow for any normal bodily movements
- Not cause skin irritations or discomfort

How can we ensure it stays on properly for consistent monitoring?

Our sensor will:

- Always stay in contact with area of skin, and stick to skin in spite of any motion
- Flex and stretch with bodily movements
- Have an adhesive strong enough to adhere to human skin and body hair after long periods of time or sweating (2.2)
- Have been tested for motion around the chest area to find optimal placement of the sensor on one’s body to ensure consistent monitoring and comfort

What type of sensor should we use?

Ultrasound Patch:

- Includes an array of millimeter-sized ultrasound transducers
- Can monitor tissues/veins up to 14 cm away (3.1) from transducer continuously in real time. Coronary arteries are typically located within that range. (3.2)

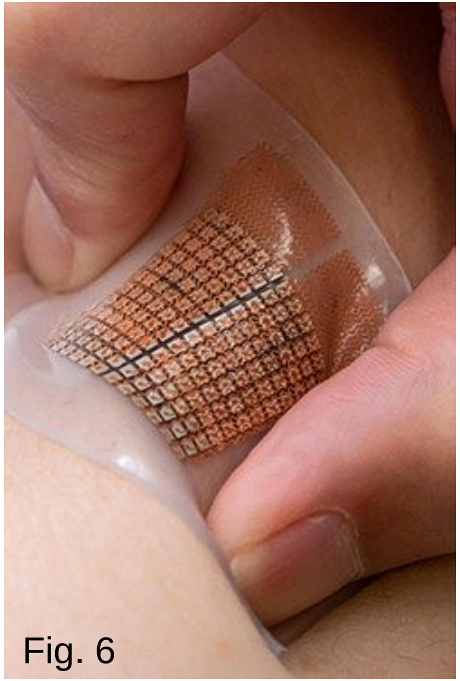


Fig. 6

Why is this a good choice?

- Ultrasound phased array technology allows the patch to detect signals over a wider area within the body
- Allows for two main modes of operations
  - Have all transducers to synchronize for focusing at a certain spot deeper within the body
  - Transducers can transmit out of sync to monitor greater general region
- Ultrasound is able to monitor the blood flow in arteries and differentiate from the flow within an organ like the heart
- Testing has found that this patch provides accurate and precise data continuously and reliably (3.1)

How can we analyze blood flow data to determine if there is a risk of heart attack?

As discussed before, a heart attack occurs when there is reduced or blocked blood flow to the heart muscles. While there are multiple ways for this to occur, it is usually caused by blockage in one of the arteries that supplies the heart muscles.

Using an ultrasound to monitor the blood flow / blood pressure in those arteries, we can determine if the individual is at higher risk for a heart attack or is having a heart attack due to a significant decrease of blood flow / significant increase of blood pressure in key areas.

Type of analysis	Data collected (input)	Insight (output)
Primary analysis:	Soundwaves	Visualised output of depth (traditional ultrasound)
Secondary analysis	ultrasound image	blood pressure at any given time
Tertiary analysis	blood pressure at any given time patient inputted data	whether or not there is a heart attack

Where data will be collected

We will be collecting and analysing data from the coronary arteries that supply blood to the heart, as opposed to the coronary veins, which leave the heart. This will allow us to predict a heart attack and monitor the situation continuously.

If we instead collected blood pressure/ flow data from the veins leaving the heart, we would only be able to to confirm that a heart attack already took place (indicated by the cessation of blood pressure/flow.

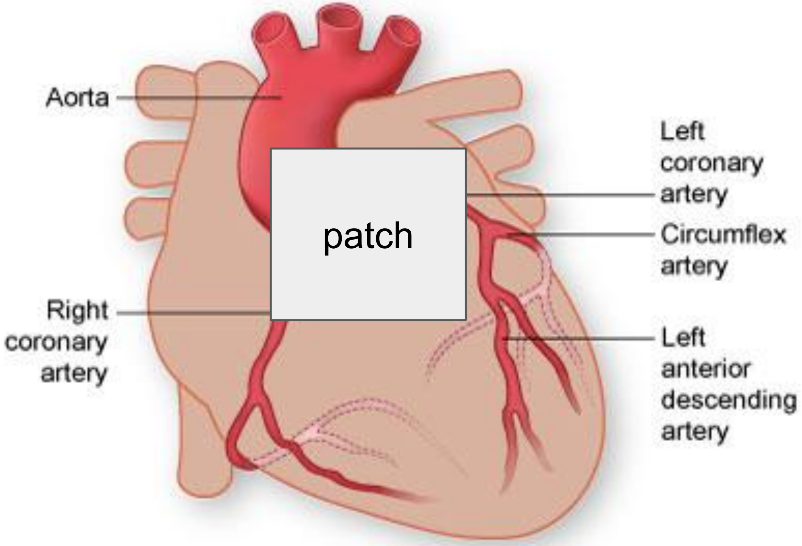


Fig. 7

Primary analysis

For the primary analysis, the ultrasound emits sound waves and then detects the waves bouncing back from the tissue.

Using the time of each wave’s return, the scanner will be able to calculate the distance (depth) between the tissue boundary and the ultrasound.

This data will then be used to create a two-dimensional image of the tissue, organ, or, such as in figure 8 and 9, coronary arteries. (4.1)

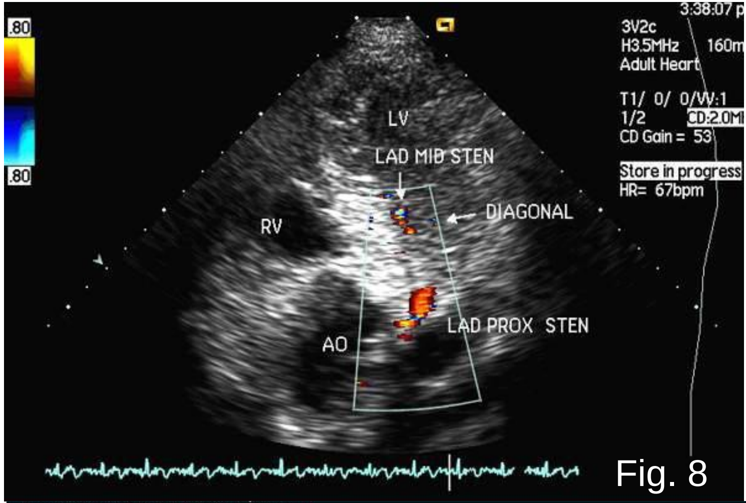


Fig. 8

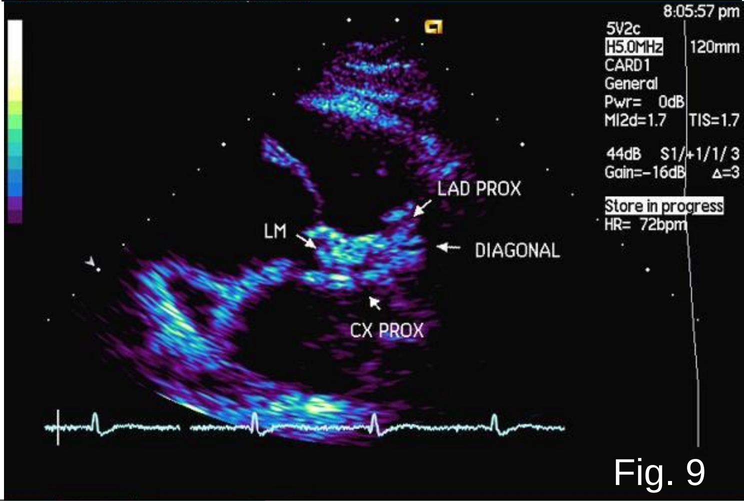


Fig. 9

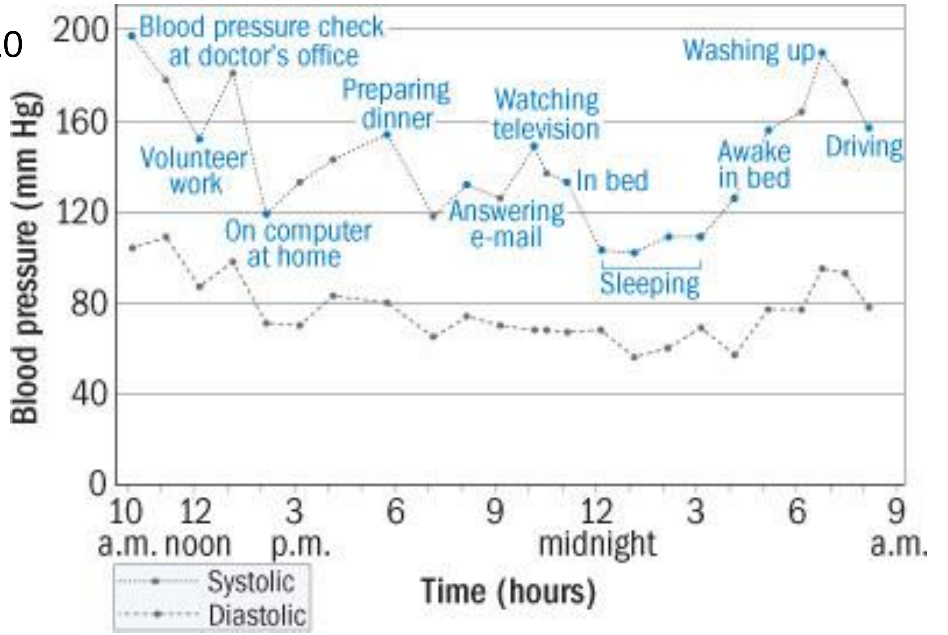
Secondary analysis

For the secondary analysis, our device will calculate the blood pressure inside of the blood vessel over time.

This will be calculated using mathematical models based on the visualisation of the blood flow and the motion of the blood flow wall (4.2).

This data will be displayed as blood pressure or blood flow over time.

Fig. 10



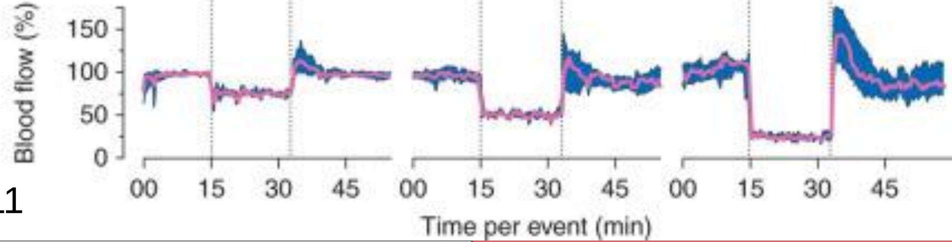


Fig. 11

Tertiary analysis: analyzing the data to assess risk

Using the obtained ultrasound data, we will be able to determine decreases in blood flow in the arteries leading to the heart muscle. (4.2) However, that data alone is not enough to determine an increased risk for a heart attack.

Our heart rate fluctuates, from a range at rest between 60 to 100 beats a minute for an adult, to an increased rate to match the level of exertion of the activity we are doing or excitement. (4.3) The increased heart rate means an increased effort of the heart muscles, which requires increased blood flow in the coronary arteries.

This fluctuation may cause a decrease in blood flow / increase in blood pressure without there being a heart attack. Therefore, we have two additional methods of determining whether the detected decrease in blood flow is normal or abnormal.

Tertiary analysis

As we have established not all decreases in blood flow or increase in blood pressure are related to heart disease, we came up with two method to differentiate normal blood flow/pressure changes from abnormal ones:

Method 1: **Arterial comparison**

Method 2: **Daily analysis**

Tertiary analysis

Method 1: Arterial comparison

Normal fluctuations in heart rate and blood pressure typically occur fairly evenly throughout the body.

- Thus, If we compare the blood flow to the different arteries during a normal fluctuation, they would all have fairly close blood flow/pressure.

- However, during a heart attack, the blood flow through one or more of the coronary arteries would be much lower compared to the others.

Tertiary analysis

Method 2: Daily analysis

- A baseline for the individual will be determined, to which we can compare our data to see if a heart attack is occuring.
  - This baseline is based on:
    1. the biometric data of the individual over a certain period, and
    2. their description of what they were doing at moments of increased/decrease blood pressure/flow, inputted by the patient

- Based on the individual baseline, the patient's physicians will indicate the significant threshold for change in blood flow/ pressure that will trigger an alarm.
- Machine learning will be applied to the combined data to extrapolate future patterns and improve the baseline over time.

Tertiary analysis: Applications

Finally, the continuously collected data and analysis from the patch can be shared with the patient's physician and can be connected to an app to warn the individual and their care team of any dangerous developments.

Such data and analysis, including a significant increase in blood pressure or a decrease in blood flow in a specific coronary artery, will allow for a quick and effective detection of early coronary disease and optimise treatment.

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Image Source

Fig. 6: *Wearable ultrasound patch could warn of cardiovascular problems* (2021). Available at: https://newatlas.com/medical/wearable-ultrasound-patch-cardiovascular-problems/ (Accessed: 20 August 2021).

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