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**Review Article**

# A review of technologies for heart attack monitoring systems

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## Abstract
***Every year, approximately 1.35 million people die in car accidents. One of the causes of traffic accidents is a heart attack while driving. Common heart attack warning signs are pain or discomfort in the chest or one or both arms or shoulders, light-headedness, faintness, cold sweat, and shortness of breath. When having a heart attack, a car driver has strong pain in the centre or left side of the chest. Current technology for heart attack detection is based on sensory signal properties such as the electrocardiogram (ECG), heart rate and oxygen saturation ($SpO_2$). This paper is intended to give the readers an overview of technologies for heart attack monitoring system that has been used at the hospital, at the home and in the vehicle. The result shows that ECG, heart rate and $SpO_2$ properties are mostly used by numerous researchers for heart attack monitoring systems at hospitals. Meanwhile, many researchers developed a system by using heart rate, ECG, $SpO_2$ and images as properties for heart attack monitoring systems at home. Existing technologies for heart attack monitoring systems in the vehicle used heart rate and ECG as properties in a system. However, there are no review papers yet on heart attack monitoring systems using image processing in vehicles. We believe that researchers and practitioners will embrace this technology by addressing image processing in the heart attack monitoring system in vehicles.***

## Keywords
***Heart attack, Heart rate, ECG, $SpO_2$, Monitoring system.***

## 1.Introduction
With the increasing number of people in the world and recent changes in human lifestyles, the trend of people with complicated medical diseases especially those related to the heart is on the rising. Many people die as a result of late heart attack diagnosis or rescue. It is critical to create a system that can aid in the early detection of heart attacks [1]. This paper's main focus of the technologies review was divided into three application areas. There are heart attacks at hospitals, in homes and in vehicles. These application areas were chosen because these places are always used by people. Nowadays, a heart attack is a dangerous disease worldwide. Furthermore, the phenomenon of heart attacks during the Covid-19 pandemic season, which leads to the death of people, has doubled thus causing concern. Statistics released in 2020 reported that heart attacks are the number one cause of death in Malaysia and on average, 50 people die due to heart attacks every day [2].

Besides, more than 23% of adults die due to heart attacks or cardiovascular disease with the latest trend showing that individuals as young as 30 years old are susceptible to heart attacks [3].

The rising cases of car accidents in Malaysia show linearly increased over the last ten years. Every year, approximately 1.35 million people die in car accidents; on average, 3,700 people die on the roads every day [4]. Many factors contributed to the car accident, such as driver behaviour, careless pedestrians crossing the street, drunk and drugs, fatigue and drowsiness, others and not known [5]. Besides that, a medical condition also contributed to a car accident [6]. From the perspective of medical conditions, car accidents are caused by pre-existing medical conditions such as eyesight problems [7], seizures [8], heart disease [9] and diabetes [10].

Ischemic heart disease is one of the most common causes of sudden death that can be happened in hospitals, at home and during driving. Some patients die quickly during a critical incident of ischemic heart disease, and there is no time for treatment [9].

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According to statistics on causes of death in Malaysia 2021, Department of Statistics Malaysia (DOSM), ischemic heart disease remained the principal cause of death, which is 17% in 2020. 20% of ischemic heart diseases are aged between 41-59 years old. Besides, 18% are aged 60 years and above [11]. Ischemic heart disease can ultimately lead to a heart attack [12].

There are many symptoms of a heart attack. According to American Heart Association [13], chest pain or discomfort are the most common signs of a heart attack. Most heart attacks are defined as pain or discomfort in the center or left side of the chest that lasts longer than a few minutes or that disappears and reappears. Uncomfortable pressure, squeezing, fullness, or pain are all symptoms of discomfort. A heart attack might be detected by pressure on the left side of the chest. It feels like someone sitting in a chest [14]. Other symptoms include weakness, light-headedness, or faintness. It's also possible that it will break out in a cold sweat. A heart attack can also cause pain or discomfort in the jaw, neck, or back. Other signs of a heart attack include pain or discomfort in one or both arms or shoulders, as well as shortness of breath. Shortness of breath commonly occurs in conjunction with chest discomfort however it can also occur independently of chest discomfort [15].

Recently many cases of heart attack occurred in hospitals and homes, especially in patients with heart disease and elderly people. The common symptoms and signs of heart attack among them are pain or discomfort in the jaw, neck, or back; feeling weak, lightheaded, or faint; chest pain or discomfort; pain or discomfort in the arms or shoulders; and shortness of breath[16]. The American Heart Association lists "uncomfortable pressure, squeezing, fullness, or pain in the centre of the chest" as the very first sign of a heart attack. This discomfort could come in waves that last longer than a few minutes [17]. Hence, early detection of this chest pain symptom might reduce the pain to worsen. In this paper, image properties become a major contribution to heart attack monitoring systems. It is because the chest pain symptom cannot be observed by using signal properties.

The symptoms of chest pain can affect the car driver's behaviour. When having a heart attack, a car driver has strong pain in the left side of the chest [18]. Automatically they will hold their hands at a chest. The hands are either one or two hands at a chest. When a driver has a sudden health problem, such as a heart attack, he or she is unable to manage the vehicle since it is difficult to move the hands during a heart attack. This situation can lead to losing control of the vehicle during the attack, resulting in accidents [19]. Therefore, early detection of this situation can help to reduce the number of accidents. That, motivates us to find out the solution for chest pain detection.

Technologies for heart attack monitoring systems have been developed by several researchers to monitor heart attacks and are normally used at the hospital, at home and in the vehicle. If a heart attack is suspected, fast recognition of symptoms and action to receive treatment can reduce the risk of complications and death [20–22]. The main objective of this paper is to review the technologies that have been used for heart attack monitoring systems, especially in the hospital, at home and in the vehicles that utilise the image properties as the input signals.

Monitoring systems have been developed to trigger heart attacks by converting any features into a new form such as electrical signals, sensory signals and image properties. *Figure 1* shows a block diagram for a heart attack monitoring system using an image property as a feature. Hence, the main motivation of this paper is to review the features used for the developed technologies in heart attack monitoring systems.

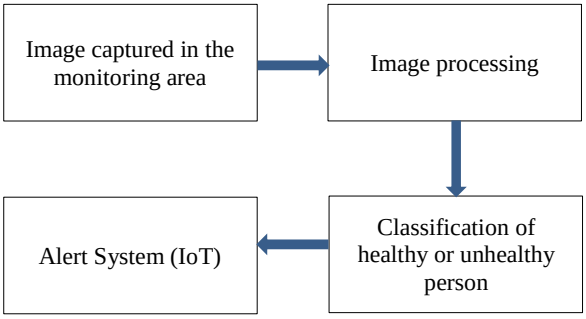


**Figure 1** A block diagram of the heart attack monitoring system

The primary goal of this paper is to identify the technologies that have been used for heart attack monitoring systems at the hospital, at home and in the vehicle. The research questions of this paper are:
RQ1. What are the technologies that have been used for heart attack monitoring systems?
RQ2. Are there any image properties features that have been used for heart attack monitoring systems?

RQ3. What are the challenges for heart attack monitoring systems?

This paper consists of six sections. The introduction is presented in Section 1. Section 2 discussed the review methodology. In Section 3, the literature review is presented. In Section 4, the analysis of features used in heart attack monitoring systems is presented. The discussion is covered in Section 5. Finally, conclusions and future works have been provided in Section 6.

## 2.Review methodology

The main focus of this paper is on the technologies for heart attack monitoring systems. Various digital sources, including IEEE Xplore, ScienceDirect, Springer, ResearchGate, MDPI, Academia and others, were initially searched to discover the papers linked to heart attack monitoring systems. The keywords like heart attack, symptom of heart attack, technologies on heart attack monitoring systems and features of heart attack are used to search a relevant paper for literature. The first process of filtering the paper is based on the title, an abstract and a conclusion. Next, the complete papers are identified by a full reading of the papers.

A total of 350 papers on heart attack monitoring systems published between 2010 and 2022 were identified. After the screening and eligibility process, 79 papers were selected for analysis. These selected papers are based on the inclusion and exclusion criteria in *Table 1*. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [23] style of representation used for selected papers is illustrated in *Figure 2*.

**Table 1** Inclusion and exclusion criteria

| | **Inclusion criteria (IC)** |
|---|---|
| IC1 | Papers from heart attack monitoring systems especially at the hospital, at home and in vehicles were considered |
| IC2 | Papers with the same method and review were considered |
| IC3 | Published papers with full online details were considered |
| | **Exclusion criteria (EC)** |
| EC1 | Only English papers were considered |
| EC2 | Excluded the paper that is not fully online |
| EC3 | Excluded the paper with other illness than a heart attack |

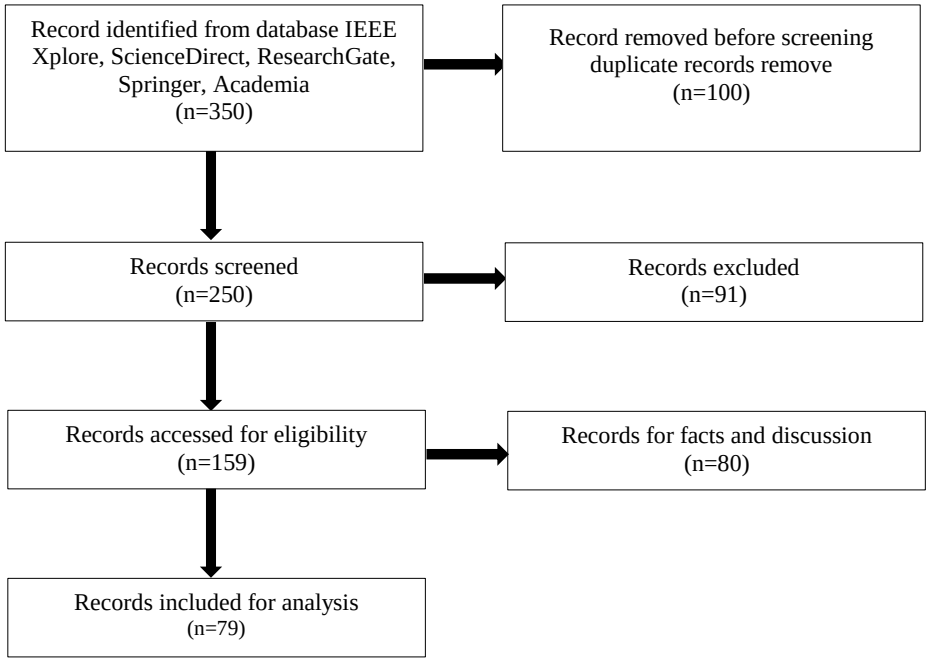


**Figure 2** PRISMA style of representation used for selected papers

*Table 2* displays a year-wise count of papers related to the technology of heart attack monitoring systems. Relevant literature from a variety of sources, including journal articles, conference proceedings, books, newspaper articles, and web pages have been gathered to cover the whole of the heart attack monitoring system in our classification. From the table, it is stated that more journal papers than conference papers are published, and the majority of these papers are from the years 2017 to 2022. A number of papers considered year-wise along with the percentage distribution are shown in *Table 3*. The percentage distribution is wide between the years 2017 and 2022, with percentages of 10.13%, 16.46%, 21.52%, 18.99%, 12.66%, and 8.86%, respectively. This is due to our review of the most recent trends and technology in heart attack monitoring systems for the years 2017 to 2022. The paper's distribution on different publishers is represented in *Table 4*. With 27 papers, IEEE Xplore is where the bulk of the papers was reviewed.

**Table 2** Year-wise count of papers related to heart attack monitoring systems

| No | Year | Journal articles | Conference papers |
|---|---|---|---|
| 1 | 2010 | 1 | 1 |
| 2 | 2012 | 0 | 1 |
| 3 | 2014 | 1 | 1 |
| 4 | 2015 | 1 | 0 |
| 5 | 2016 | 2 | 1 |
| 6 | 2017 | 5 | 3 |
| 7 | 2018 | 9 | 4 |
| 8 | 2019 | 8 | 9 |
| 9 | 2020 | 11 | 4 |
| 10 | 2021 | 5 | 5 |
| 11 | 2022 | 4 | 3 |

**Table 3** Number of papers considered year-wise along with the percentage distribution

| No. | Years | No of papers | Percentage |
|---|---|---|---|
| 1 | 2010 | 2 | 2.53% |
| 2 | 2012 | 1 | 1.27% |
| 3 | 2014 | 2 | 2.53% |
| 4 | 2015 | 1 | 1.27% |
| 5 | 2016 | 3 | 3.80% |
| 6 | 2017 | 8 | 10.13% |
| 7 | 2018 | 13 | 16.46% |
| 8 | 2019 | 17 | 21.52% |
| 9 | 2020 | 15 | 18.99% |
| 10 | 2021 | 10 | 12.66% |
| 11 | 2022 | 7 | 8.86% |

**Table 4** Papers distribution based on different publications

| No. | Publication | No of papers | percentage |
|---|---|---|---|
| 1 | IEEE Xplore | 27 | 34.18% |
| 2 | ScienceDirect | 6 | 7.59% |
| 3 | ResearchGate | 12 | 15.19% |
| 4 | MDPI | 2 | 2.53% |
| 5 | Springer | 2 | 2.53% |
| 6 | Academia | 3 | 3.80% |
| 7 | Others (Nature, Hindawi etc) | 27 | 34.18% |
| Total | | 79 | 100 |

# 3.Literature review

## 3.1Heart attack monitoring system at the hospital

The development of telehealth technology has greatly helped medical professionals in efficiently reducing patient illness from worsening. Remote medical technologies such as glucose monitoring, blood pressure monitoring, electrocardiogram (ECG), and pacemakers have helped to reduce medical personnel's workload and the number of patients registered at a hospital [24]. A new medical monitoring system that is based on telehealth technology to detect a patient's heart attack is required. This is because it is very crucial to treat a heart attack patient immediately before the condition becomes worsens. Every second is a valuable time for heart attack patients either live or died. Therefore, a continuous monitoring ability is required at the hospital so that the patient may be monitored in real-time [25].

A heart attack monitoring system can give many advantages to patients and doctors, especially in hospitals. The recording of ECG signals is a standard method for monitoring cardiac function and for detecting heart attacks or abnormal heart rhythms. The technology used 12-lead ECG data, and the results can be used to identify the location of myocardial infarction (MI). According to the author, the technology has high accuracy and sensitivity performance on ECG lead signals. It is essential to identify the location of MI due to the ECG signal. Hence, medical assistants can provide accurate diagnoses to avoid death. Similar works with ECG signal to identify MI was upgraded by incorporating an intelligent system [26] to classify the MI. The success of intelligent systems to diagnose ECG signals also have been proved by [27–29].

Besides, other technology devices are also used to monitor the physiological parameters of cardiac patients. Non-invasive testing can be performed to evaluate the physiological parameters of the heart and arteries at the body surface, which can be used to detect the multiphysics mechanisms of the cardiovascular system [30]. In [31], a healthcare monitoring device for cardiac patients describes a monitor's physiological factors of cardiac patients such as heart rate, temperature, and oxygen saturation ($SpO_2$) levels. This device presented a three-tier design for a prototype healthcare monitoring system that uses a wireless sensor network (WSN) to continually monitor a patient's body parameters. The benefits of this technology include the ability for caregivers and medical staff to continuously monitor and store patient body parameters. In addition, the technology is also useful for continuous cardiac patient monitoring in hospital intensive care units due to the limited number of medical staff [32].

Another advantage of a heart attack monitoring system is that it can reduce the time it takes to receive standard treatment, as well as the rate of death and infarction damage [33]. Introduced a system for medical staff to employ in monitoring and alerting abnormal heart rate readings in patients [34]. Photoplethysmography (PPG), a technique that uses a photo transmitter and detector to evaluate the variation of tissue blood flow rate, is used in this device. The author believes that this technique is a smart way to make it easier for medical personnel to get a quick alert in an emergency. A quick alert of a heart attack can save a patient's life. In [35], a system that monitors heart attacks using indicators of important human signs has been proposed. To detect signs of a heart attack, this system used parameters such as respiration rate and body temperature. It can be used in patients who have been diagnosed with heart attack disease to make monitoring their status easier.

In [36], a method that uses a wearable transmission to monitor the patient's health has been introduced. This wearable system, allows medical staff to monitor a patient without the need to go to the hospital for reading an ECG signal. The doctor can obtain real-time data on the patient's parameters and location, allowing for immediate medication. This technology consists of two different sensors which are a temperature sensor and a pulse sensor. The data from the device were sent to the server via the patient's Android application. The doctor can have access to the data via his computer. The wearable and wireless ECG was inspired by [37] the intelligent telecardiology system for detecting atrial fibrillation. This system used Bluetooth technology which has low power consumption collects data and transfers it to a remote database system. The aberrant ECG signal is transmitted and activates the alert messenger system, which sends a message to a cardiovascular ward's nursing station. Similar work also has been presented by [38].

After a decade, with the aim of monitoring everywhere, the portable ECG smartwatch was introduced [39, 40]. The smartwatch could also monitor vital parameters including the ECG and heart rate, blood oxygen levels, skin temperature and moisture, and the patient's physical activity. A smartphone was used to report anomalies in the pattern of a patient's health state to medical staff. A year later, the ECG watch, a real-time wireless wearable ECG was introduced to address the problem of random ECG anomalies such as atrial fibrillation [41]. Today, the ECG smartwatch was widely used for personal health monitoring systems.

The advancement of medical electronics and communication technologies led to an Internet of Things (IoT) technology where the doctor continuous monitoring of the patient without physically visiting the patient. IoT technology is becoming a major platform for many services and applications including medical applications. The advancement of healthcare from face-to-face consultation to telemedicine has been aided by the advent of IoT technologies [42]. This technology presented a smart healthcare system that can monitor a patient's basic healthcare parameters as well as the room condition where the patients are now in real-time in an IoT environment. IoT technology is also used by [34, 43, 44] for heart rate monitoring for a patient. The internet's innovation has given rise to a plethora of cloud platform technologies. The cloud platform is important for both storing and accessing data. By storing and monitoring all wearable sensor data on the cloud, health professionals would be able to access and retrieve data from anywhere in the world [45]. A novel solution has been offered by [46] for early detection and medical treatment in the instance of a heart attack. To patients with heart disease, the author introduced a new product (a sensor and a smartphone app) and also a new service (medical advice as a service). A patient's wearable ECG sensor transmits signals to the patient's smartphone (or mobile device), which subsequently transmits the signal to the cloud-based data centre. For people in

critical health conditions, monitoring vital signs such as heart rate and body temperature is essential since they can be signs of other diseases [47]. Heart Monitor is a system created to measure patients' heart rates and body temperatures and store them in cloud services.

Conducted a system for developing an effective technique for acquiring clinical and ECG data to train an artificial neural network to accurately identify heart problems if any exist[1]. This proposed system can diagnose in a shorter period, and an artificial neural network can be used to create a system that can detect heart attacks. With advances in digital image processing, healthcare systems today heavily rely on medical information systems to extract insights from medical images [48]. The non-invasive way through Cardiac Computed Tomography Angiogram images has been used by the author for early detection of disease. Coronary artery disease produces a waxy material called plaque to clog the coronary artery, resulting in a heart attack.

### 3.2Heart attack monitoring system at the home

The implementation of home health care systems using new technologies has rapidly increased. All these technologies can provide many benefits and advantages to anyone such as cardiac patients, infant or baby care and elderly care at home [31]. Home health care monitoring can be divided into two types. There are traditional health care monitoring and modern health care monitoring. Face-to-face home healthcare visits are referred to as traditional healthcare monitoring. Professional health services such as clinical and medication monitoring, as well as home care education, are generally provided to homebound patients by skilled nursing personnel that travel to the patient's home [49]. A study by [50] explains that Medicare-certified home health firms are experts at providing in-home skilled nursing and therapy services to patients recovering from acute illnesses. However, this approach gives a high cost to a patient because a patient needs to pay to hire a skilled nurse at home. Especially for a lower income group, they're unable to hire a skilled nurse at home. While, modern healthcare monitoring is a system that makes use the new technologies in the area of bio-sensing, wireless communication, mobile computing, and artificial intelligence[51]. A study on healthcare monitoring systems using biosensing has been developed by [52]. This system was designed with multiple sensors and a microcontroller to monitor a patient's environment and health. Similar works have been proposed by [53] with advanced technologies in wireless communication and mobile computing. For real-time data processing, a wireless physiological signal acquisition device and a smartphone-based software platform was used. Similar works also have been done by [21] using the technology of convolution neural network. By analysing images using a convolution neural network, the system developed an algorithm to automatically identify when a person is facing a probable heart attack. All the advanced technology that has been used by several researchers in healthcare monitoring systems can gives a high impact on patient's health.

Heart attack is a dangerous disease for all people. Almost all heart attack survivors are admitted to the hospital for further treatment of their health. After discharge from the hospital, heart attack survivors are still at risk for a second heart attack. According to [54], heart attack survivors who receive home health care after a heart attack are less likely to be readmitted to the hospital within the first month. Furthermore, adopting home health care after discharge for heart attack patients can help patients and medical systems reduce the cost of health care. It also has been proven by [31]. Heart attack survivor needs to monitor their health condition at anytime and anywhere. Therefore, special or extra monitoring for precautions is required to save a life. For example, it is a dangerous situation if an adult is sleeping at home and got a sudden heart attack. The doctor is not at home to assist and provide rapid medical treatment [52]. The situation becomes worse if there's nobody notices the survivors are having a heart attack. Evidence from [38, 55] proved that home health care was able to provide early heart attack detection. Thus, medical help will be given to the patient within the first few critical hours. As a result, chances of survival are considerably improved. The use of a home health care monitoring system can also aid elderly patients at home. Concluded that the system is effective for patient monitoring and aftercare in the homes of elderly patients and that the elderly feel confident using it [56].

Generally, vital sign recording and monitoring are important elements of home healthcare [57]. Vital signs are indicators of the body's most fundamental functions. The key vital signs observed by medical professionals and health care providers are body temperature, pulse rate, respiration rate, and blood pressure. Vital signs are used to detect or monitor medical issues. Vital signs can be checked in a hospital, at home, during a medical emergency, or

anywhere else [58]. Several studies have been developed on vital signs monitoring to detect a heart attack. For patients with a history of heart attack, created a device that monitors vital signs and detects anomalies such as heart rate, body temperature, $SPO_2$, and respiration rate. Similar works also have been presented by [59–61].

A similar approach was employed by [62] with the improvement of IoT technology. Heart attacks can thus be identified and lives saved with the use of IoT. With advancements in IoT technology, it is now possible to monitor a patient's heart rate immediately at their home. Created a heartbeat monitoring and detection system that makes use of the IoT[55]. The system was created by using a heartbeat sensor to detect an individual's heartbeat using a heartbeat sensor, regardless of whether the individual is at home. An advancement of IoT technologies also has been used by [63] as a new ECG control method. ECG screening has been extensively researched and used as a key approach to detecting heart disease. The ECG data is collected using a wearable tracking node and sent straight to the IoT cloud through wireless fidelity (Wi-Fi). Furthermore, an intelligent system was integrated into the heart rate monitoring system, which predicts the severity of heart disease without the need for periodic ECG tests. This intelligent system with IoT technologies has been developed by [64, 65]. Similar work has been improved by [66] that focused on WSN. The ECG signals are continually captured and transmitted to the patient's mobile phone via a wearable wireless sensor system. For real-time monitoring and identification of heart attacks, the system used a wireless sensor network, a mobile phone, a global system for mobile communications (GSM), and a global positioning system (GPS). The use of this technology will help to reduce heart disease which can lead to mortality, as well as provide an effective health care service to people in rural areas.

Wearable devices that collect biometric data are becoming more widely available, and their application in daily activities is becoming more popular. These small electronic devices have been widely used in industries such as medicine, healthcare, and fitness to track fitness and health-related outcomes [67]. Wearable technology is also an important element in home healthcare monitoring. Developed a wearable cardiorespiratory monitoring device that can detect a heart attack [59]. The device could concurrently monitor and show four parameters on a phone or computer screen in real time. The advantages of the device are low-cost and small enough to be worn on a routine basis. Wearable devices are now used for a wide range of health observation purposes. Due to that, proposed a smart wearable system capable of monitoring a patient's heart rate condition. Through Bluetooth technology, this wearable device measures heart rate. If a patient's beats per minute (BPM) becomes unstable, the app sends short message service (SMS) notifications to a medical expert's or a patient's family member's or relatives' phone. The patient's current location and status are included in the SMS. The ability to use a device in the real world, performance, efficiency and power consumption were the most important criteria in this study. Similarly, wearable technology has also been applied in the work of healthcare monitoring [68, 69].

Besides that, previous studies have also been done on wearable technology for healthcare monitoring by using a smartwatch. Developed a personal healthcare system that allows users to track their daily activities such as exercise, sleeping, heart rate, and diet with just a smartwatch and phone [69]. The smartwatch is used to sense and collect data, including a user's heart rate. This system makes use of a commercial smartwatch (Cling), which has a Bluetooth connection and four different types of sensors. A belt is also a wearable device that has been used for home healthcare monitoring. Designed a wireless belt that continuously monitors a person's heart rate and temperature [60]. This device may monitor a person's health regularly, lowering the risk of a heart attack. However, all these wearable devices have a drawback where patients or people need to wear a device all the time and are sometimes distracted.

With advances in technology, it is now possible to monitor elderly people in their homes. Nowadays, people and elder people find it difficult to go to the hospital for their routine checks in today's hectic world due to a lack of time [70]. A robust mathematical model that can assist prevent a patient from having a heart attack by sending a message or email to their phone has been developed. A benefit of this system is that enrolled patients will be informed in real-time, potentially saving their lives from a heart attack. Several studies have been done on home healthcare monitoring systems to help elderly persons who are more susceptible to heart disease. Created a system that monitors the user's heart rate, temperature, and sweating and sends out SMS alerts when it reaches dangerous levels [71]. This system is cost-effective and portable, and it was designed for

the elderly population (mostly those who have already had a heart attack), who are predominantly pensioners or rely on other sources of income. Similar works that focused on the elderly also have been done by [72] that proposed an integrated system for monitoring elderly people's health. The system described an effective data preparation strategy for extracting raw data from an electronic wearable tracker and a station-based health monitoring device. It's a novel way to process these data for practical purposes. Aside from that, the system can identify whether an elderly person's health would better or worsen. This is a critical and fundamental problem because it is a direct indicator of some severe health implications. Numerous studies have explored the usage of home healthcare monitoring [73, 56] has been proven to be very important for reducing the chance of heart attack for elderly people.

Besides, several works [74–77] have focused on the fall detection system. The system aims to detect sudden falls by heart attack survivors. The works [69] proposed an android smartphone featuring a three-axis accelerometer. This smartphone acts as a telehealth device that can detect a carrier's fall. The monitoring system is then connected to the smartphone through Wi-Fi utilizing the transmission control protocol/internet protocol (TCP/IP) networking method. As part of the monitoring system, a graphical user interface (GUI) is created that presents the data collected by the system. Similar approaches have been improved by [78] with the technology of IoT. In the design of a "smart safety band," this system proposed a novel and innovative IoT-based solution. This system can detect falls and sudden heart attacks by combining numerous sensors with a microcontroller that sends data directly to a web server.

### 3.3Heart attack monitoring system in the vehicle

Heart attack is a serious disease among vehicle drivers. According to the research, 60% of people had a heart attack while driving [79]. Unexpectedly, many fatal accidents occur as a result of a driver's heart attack, which causes the car to lose control [21]. Therefore, a technology for heart attack monitoring must be developed to save a driver at a wheel.

Nowadays, several researchers have developed a heart attack monitoring system in vehicles. Vehicle drivers got a lot of benefits and advantages with the existence of the system. Invented a device that detects heart attacks in the car [80]. An interactive steering wheel system has been designed to identify the signs of an early heart attack for car drivers with a history of chronic heart disease. Noninvasively, the designed device monitors the driver's heart rate, body temperature, and skin resistance. While the driver's qualitative symptoms of dizziness, nausea, exhaustion, chest pain and numbness in the left hand are corroborated by an interactive system that asks the driver about his or her current physical state in an unobtrusive way. A steering wheel by utilizes commonly available and low-cost components has been designed by [81]. On a steering wheel, the created system used the principle of non-contact ECG. To provide real-time heart rate monitoring, this system used a simple analogue signal conditioning circuit and a digital processing unit. Similar works on the development of steering wheels have been done by [82–84]. This device can assist people who have a history of chronic heart disease in avoiding car accidents while driving.

Presented a wearable and portable technology for monitoring heart attacks [22]. This system advocated the implementation of a wearable device for detecting and warning heart attacks in drivers in real time, which may be extremely useful in minimizing road accidents. Anyone who had a previous history (or even without previous history) of heart attack can use this approach in a variety of situations (e.g., at work, home, driving, etc.). In addition, if the collision is caused by the driver's illness, this approach can assist the driver in obtaining insurance benefits. Works on how to reduce road accidents also have been explored by [85] who designed a system for accident detection using a heart rate monitoring device. This technology is utilized in emergencies, such as when someone is driving a car and suffers a heart attack. To bring the situation under control, this monitor device would transmit an alert to an Android-enabled phone, which would then cause the car to come to a halt, preventing future casualties. Described a system that allows the apps to locate and route the driver to the nearest hospitals [86]. In this method, autopilot assistance will be enabled if the situation is serious and the driver is not reacting to the drive. A portable safety kit has been developed by [87] to reduce the rate of human mistakes and the number of accidents. The heart rate of a driver was monitored using PPG sensors. This safety kit is cost-effective when compared to a single technology given by car manufacturers. Developed a system which is proved that the technologies can prevent an accident caused by human error [79, 88].

From the perspective of cost, [19] investigated a project that would benefit persons in the middle-class economy. This technology was offered to conventional and lower-end cars, as well as truck drivers in India, where truck driver safety is lacking. This system used a pulse sensor and temperature sensor to monitor a health condition of a driver. The pulse sensor is attached to the driver's seatbelt. The seatbelt is fastened around the driver's chest to determine the pulse rate. The temperature sensor, which is mounted in the driver's seat, detects body heat and oxygen levels in the blood. These sensors are controlled by Arduino as a microcontroller. When compared to other safety systems, the cost of this system would be extremely inexpensive and it could be easily commercialized even by ordinary people. It is because the sensor and Arduino that have been used in this system are cheap and easy to use. Developed a system to monitor the heart rate of passengers using a low-cost camera that can easily be integrated into the rear-view mirror of a vehicle [89]. This method is based on remote PPG (rPPG), a process that extracts the heart rate from subtle variations in the skin colour of the face during each pulse. This system uses a low-cost camera that everyone can use this system to monitor heart rate in the car. Low-cost technology for health monitoring in the vehicle also has been approved by [90]. This technology is a user-friendly, low-cost and effective alternative to monitoring heart rate, skin conductivity and vehicle speed. Facial expressions have been used in this system to monitor a driver's status by using a deep neural network. Furthermore, this system is cost-effective because there's no need to use a sensor to monitor the heart rate of a driver. Similar works on designing a low-cost heart rate monitoring technology in vehicles also have been done [91, 92].

Besides, leveraging IoT technologies and wearable devices, [86] designed a health monitoring and emergency help system. An Apple watch as a wearable device was fully utilized in the system. A driver must have an Apple watch, and the health detects and health locates applications downloaded from the Apple store. However, the limitation of this system is it cannot be used on another watch except the Apple watch. Proposed a smart watch-based heart rate variability monitoring system (S-HRVM) [93]. This technology created a precise and portable monitoring system with high robustness that can be embedded in mobile devices to detect the user's HRV. The smartwatch was used to track the user's heart rate. Furthermore, this system was created to work with any smartwatch that has a built-in heart rate sensor. Similar work on smartwatches also has been developed by [94, 95]. Similar approaches have been improved by [96] with the technology of IoT. The Real-time Heart Attack Mobile Detection Service (RHAMDS), a novel IoT e-health service, has been proposed to employ voice and gesture control on smartwatches. This technology attempts to reduce and prevent vehicle collisions by detecting drivers who may be suffering from heart attacks. Numerous studies have explored the advancement of IoT technology in health monitoring systems for car drivers. Devised a system to detect any abnormalities in a driver's condition [79]. The system will transmit a GSM alert and will be easy to monitor through a wireless connection. When the heartbeat sensor, blood pressure sensor, eye blink sensor, alcohol detector, and vibration sensor detected an abnormal situation, the IoT played a key role in collecting data. Similar works on the usage of IoT have been explored by [97–100]. However, the limitation of this advanced technology is the internet network must always be connected.

Nowadays, it is crucial to have a system for tracking heart attacks in patients while driving and sending the information to medical alert. Created a system to monitor the cardiac patient while driving [101]. A heart rate sensor is used to detect any abnormalities in the driver's heart rate. This system automatically stops the vehicle if the heart rate was abnormal. This is essential to ensure that the driver and the people around them are safe. Then, a microcontroller sends information about the vehicle number & the mobile number of the driver to the nearest medical station within 25 km for medical aid via Tarang F4. Tarang F4 is one of the Zigbee modules for interfacing with the microcontroller and can allow communication between the vehicle and the hospital. The advantage of using Tarang F4 is it has a larger coverage area. However, safety issues arise when the car is stopped or breaks immediately which will lead to a road accident. Similar work has been created by [86] with an improvement on the autopilot system. This technology allows the apps to locate and route the driver to the nearest hospitals. Besides, autopilot assistance will be enabled if the situation is serious and the driver is not reacting to drive.

Accidents can be avoided by constantly monitoring drivers. Numerous studies have explored constantly monitoring the driver's heart rate and ECG reading while driving. Developed a system to monitor a driver by using a heart rate sensor [102]. The sensor is clipped on a driver's fingertip or earlobe and

continuously monitors the heart rate of the driver. Furthermore, a microcontroller has been used in this system to control a motor driver (L293D) to stop the engine if the heart rate is less than 40 or more than 100. This system is portable and suitable for implementation in all vehicles. The same work has been designed by [103]. However, the continuous clipped sensor on the fingertip or earlobe can give an irritated feel to the driver. Besides, [104] presented a system that used ECG and PPG sensors to compare and evaluate heart rate and heart variability data for emerging heart disease, stroke, or any emergency condition. A high-resolution proximity sensor with a programmable light-emitting diode (LED) current at the ear and an electrical change sensor with electrodes were used at the chest to measure heart rate and heart rate variability data while driving. However, there is also a limitation to this technology which is a driver must wear the PPG sensor on the ear and the ECG sensor on the chest to keep track of and complete preliminary testing. Similar work also has been done by [105] using smart bands/health bands, which are widely accessible on the market. These smart bands will constantly monitor a driver's heart rate. When a driver's heart rate falls below a dangerous level, the nearby smartphone will be notified. A drawback of this system is the driver must wear the band all the time while driving.

Numerous works have explored ECG signals as a feature used to monitor a driver's health condition. Developed a system that used capacitive ECG sensors to measure the driver's heart rate [106]. The capacitive ECG measurement device (which included electrodes integrated into the driver's seat as well as electronics) was installed in the car. An algorithm (based on principal component analysis) to detect and discard time intervals with artefacts is described to enable robust and reliable estimation of heart rate. In highly distorted ECG signals, the proposed algorithm enables the identification of useful and reliable intervals. Similar work has been done by [107]. A smart device has been created for a driver to record ECG signals. The ECG signal is corrupted in a driving environment due to different artefacts imparted to the signal. To achieve an accurate result of heart attack detection using ECG signals, these artefacts must be removed. Matlab software has been used to remove artefacts. Besides, the same work also has been done by [108] with a combination of capacitive ECG recording and beat-to-beat interval estimation. This technology focused on drivers or patients after major cardiac events. It is proven that cECG can be used to detect heart rhythm abnormalities and estimate beat-to-beat intervals similar to conventional ECG.

The technologies that have been used by previous researchers for heart attack monitoring systems are illustrated in *Figure 3*. While *Figure 4* represented the features that have been used for heart attack monitoring systems. The major challenges of these technologies are how to adapt the technologies with the relevant features to develop robust heart attack monitoring systems.

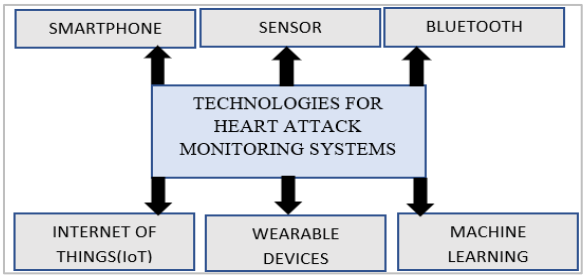


**Figure 3** Technologies for heart attack monitoring systems

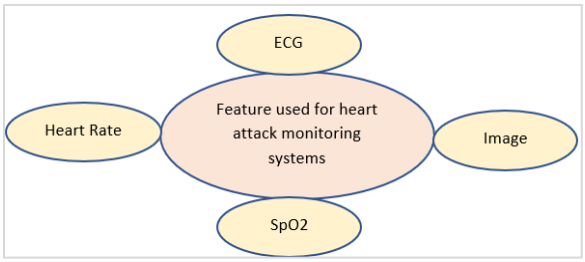


**Figure 4** Feature used for heart attack monitoring systems

## 4.Analysis of technologies and features used in heart attack monitoring system

Several features used in the heart attack monitoring system at the hospital, at home and in the vehicles have been analysed and the analysis is concluded in *Table 5*, *Table 6* and *Table 7*. *Table 5* shows an analysis of features that have been used by previous researchers on heart attack monitoring systems at the hospital. According to *Table 5*, numerous researchers used ECG, heart rate and $SpO_2$ features for heart attack monitoring systems at hospitals. ECG is the most common feature that is used by medical officers in the hospital to detect a heart attack in a patient. To measure the ECG signal and learn more about the electrical activity the heart produces, a set of electrodes are placed non-surgically on the body surface[109]. This method is frequently used in hospitals due to its lower cost and ease to use.

**Table 5** Analysis of features used in heart attack monitoring systems at the hospital

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| 1 | Yuce [24] | / | / | | | Small sensor nodes in a wireless body area network (WBAN) are currently facing hardware-related difficulties relating to the miniaturization of the sensor node electronics, particularly the sizes of the microcontroller, the wireless chip and the battery. | Low power consumption. | Medical professionals can access patients' physiological signs from anywhere in the hospital. |
| 2 | Mishra et al. [27] | | / | | | Require a lot of records data. | Can be easily implemented in areas where such expertise is not available. | Binarization based on deep learning is 97% accurate. |
| 3 | Zhu et al. [28] | | / | | | A few types of rhythm and conduction arrhythmias were not included because of an absence of patient samples. | Efficiency and cost-effectiveness in automated ECG interpretation. | 80% of the 828 ECGs (658) produced an exact match. |
| 4 | Gogate and Bakal [31] | / | / | / | | Sensors are attached or induced into the patient's body. | Continuous monitoring of patient's body parameters. | The system has a 95% accuracy and a response time of 10 seconds. |
| 5 | Rad et al. [33] | | / | | | Using Bluetooth for sending data from the data acquisition system to the smartphone facilitates time application | It is possible to make immediate contact with the doctor utilising mobile technologies like SMS and calls. | Real-time algorithm evaluation criteria were 98% sensitivity and 93.3% specificity. |
| 6 | Shah et al. [34] | / | | | | Telegram is used as a platform to send a notification if a heart rate reading is abnormal. | Provide an alternative method for the medical staff to monitor and get alerts about the heart rate of the patients. | Can be used in hospitals or by heart disease patients to periodically check on their heart rate status. |
| 7 | Zahra et al. [35] | / | | / | | The user needs to wear a belt anytime | Heart attack early detection technology to reduce the risk of sudden mortality caused by a sudden heart attack. | The biggest body temperature error was 0.55% and the largest respiratory error was 4%. |
| 8 | Gogate et al. [36] | | / | | | Users need to have an android device. | The patient's parameters and location can be obtained in real time | Medical professionals can monitor, diagnose, and advise |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | by the doctor, enabling The provision of immediate treatment. | patients on medication. |
| 9 | Yang et al. [37] | | / | | | RRI variation is used to detect atrial fibrillation (AF) when a user experiences many atrial or ventricular premature beats, which might be mistaken for AF. | Simpler, more manageable, and power-efficient implementation. | For ambulatory AF monitoring and detection, the proposed method is the most effective. |
| 10 | Subin et al. [38] | | / | | | The patient is required to carry a cell phone equipped with Bluetooth. | Highly energy-efficient since it uses an Android system to smooth and filter the ECG signals. | Offer a portable, dependable, and cost-efficient solution for health care monitoring. |
| 11 | Randazzo et al. [39] | / | / | | | The user needs to wear a smartwatch all the time | Low cost and easy to use. | A reliable tool that medical professionals and hospitals can use to remotely monitor patients. |
| 12 | Simha et al. [40] | | / | | | An internet connection is needed because the system uses wireless communication. | Low storage requirements and simple to use. | Can be utilised to produce huge data of aberrant ECG data. |
| 13 | Randazzo et al.[41] | | / | | | Patients need to wear a watch all the time. | A low-cost, wireless, wearable, unobtrusive device that records a single-lead ECG. | About 40 people have tested the device, and it has been successfully compared to a conventional 12-lead electrocardiograph |
| 14 | Islam et al. [42] | / | | | | The sensors are wired and are used to collect data from the patient's body. | Simple to design and easy to use. | The effectiveness of the system shows this prototype is well-suited for healthcare monitoring. |
| 15 | Alam et al. [48] | | | | / | There will be other regions with the heart's arteries because they are larger in size than the artery's area, and the artery has now become one connected region. | Segmentation, quantification, identification of the degree of blockage, and identification of heart attack risk factors efficiently enable early detection of coronary artery blockage. | Compared to logistic regression and linear support vector regression, Naive Bayes predictions are more accurate and sensitive. |
| 16 | Mazidi and Eishghi [110] | | / | | | Needs a lot of time to test the data concerning the size | Can identify the area of MI. | According to the results, the system's |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | of the data. | | sensitivity and precision are 96.7% and 99%, respectively, for detecting the incidence of MI. |
| 17 | Kaur et al. [111] | / | | / | | A patient needs to wear a wearable device all the time | Due to the ability of the doctor or other medical personnel to receive real-time feedback regarding the patient's health while wearing these devices, patients can receive medical assistance promptly. | Telemonitoring of patients has become a reality with the aid of wearable sensors. |
| 18 | Lin et al. [112] | / | | / | | Simulated graphical monitoring interfaces are needed | Low cost | The system can effectively overcome the limitations of conventional design methods for monitoring interfaces |
| 19 | Jayanthi et al.[113] | / | | / | | Need to constantly connect to an intranet communication and networking system, the Internet, or a Wi-Fi wireless network | IoT is used to continuously monitor all parameters and provide the data to the doctor | IoT allows the specialist or nurse to assess the patient's pulse without having to see them personally |
| 20 | Tariq et al. [114] | / | / | | | The patient must wear a heart-rate monitoring bracelet | Increased accuracy, efficiency, and dependability when monitoring the heartbeat | To analyse the heartbeat and detect the heart rate, the R language uses the Linear Regression (LM) algorithm and the Classification and Regression Tree (CART) algorithm |

Meanwhile, for home applications, many researchers developed a system by using heart rate, ECG, $SpO_2$ and image as a feature as shown in *Table* 6. Heart rate is the number of times the heart beats in a minute. Heart rate is a common feature that has been used to monitor heart attacks at home. Numerous researchers developed technology on wearable devices and sensors by using heart rate to monitor heart attacks. Several heart rate monitoring technologies especially for the elderly at home is simple and easy to use.

**Table 6** Analysis of features used in heart attack monitoring systems at the home

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart rate | ECG | $SpO_2$ | Image | | | |
| 1 | Rojas-albarracin et al. [21] | | | | / | The training of a convolution neural network cannot always be done by relying on a large enough set of data. | A convolution neural network-based algorithm might be used with robot companions or in smart and healthy environments. | The classification of infarcts yielded encouraging findings with 91.75% accuracy and 92.85% sensitivity. |
| 2 | Sorwar et al. [51] | | / | | | The patient needs a smartphone and internet connection. | Cost-effective system. | Must provide "driver software" for those functions on smartphones. |
| 3 | Kalyan et al. [52] | / | | / | | A microcontroller will be used to control the amount of drug flow as it is injected into the patient's body. | It is more flexible and cheaper than a commercial solution. | A heart attack can be monitored more quickly, easily, and reliably. |
| 4 | Polu and Polu [55] | / | / | | | Used a heartbeat sensor to detect a person's heartbeat at home. | In the server room, a single person is responsible for monitoring each patient. | Aid in the early detection of heart attacks. |
| 5 | Jalal et al. [56] | | / | | | The system is not user-friendly for the elderly. | Immediately applicable to any e-health monitoring systems, such as tracking medical issues with the elderly and the sick patient, or investigating patients' indoor activities at home or in hospitals. | In comparison to current features for recognising human action and activity, the proposed multi-features are effective and reliable. |
| 6 | Ghanadian et al. [57] | / | | | | The heart rate estimation is affected by changes in spatial and temporal illumination. | The implementation of a lighting equalisation system to reduce the effect of shadows and uneven facial lighting on heart rate estimates. | The algorithm shall measure the heart rate given that it receives a video that captures at least 50% of the subject's face. |
| 7 | Sasidharan et al. [59] | / | | / | | The hardware must be worn daily. | Wearable, inexpensive and small in size. | Heart attacks can be predicted, and individuals can be alerted in advance. |
| 8 | Patil et al. [60] | / | | | | The users have to wear the proposed belt all the time. | The simplest method to identify a heart attack. | The microcontroller is used to set the threshold value, and when the input exceeds it, |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | | the registered user is notified. |
| 9 | Li et al. [61] | / | / | | | The user needs an Android smartphone and an internet connection. | A pervasive monitoring system that can transmit patients' vital signs to remote medical applications in real time. | Can monitor the patient's physiological signs, such as blood pressure, ECG, and $SpO_2$, |
| 10 | Prema et al. [62] | / | | | | The patient has to carry the hardware all the time. | Assists the elderly, who are more susceptible to heart disease. | It is helpful to identify a heart attack and save lives. |
| 11 | Kora et al. [63] | | / | | | Use IoT technologies to detect abnormal heart conditions with wireless wearable (coat) ECG. | Cost-effective. | extremely helpful for elderly patients with serious heart problems. |
| 12 | Balakrishnand et al. [64] | / | | | | Patients need to wear a fingertip sensor all the time. | Utilising a smart fingertip heart rate sensor that continually and remotely monitors patients' blood pressure and heart rates. | Using a lightweight encryption algorithm, the results will be protected. |
| 13 | Kappiarukudil and Ramesh [66] | | / | | | Integrating other wireless network technologies with the current WSN. | Low cost. | The technology will help reduce the number of deaths caused by heart attacks and other cardiovascular conditions. |
| 14 | Ahmed[68] | / | | | | Energy-related concerns, such as battery failure or other problems, may result in a device's power down, sending a faulty or interrupted signal. | The devices can send data from a patient's home to a remote cloud server. | Second and third-level data collection will be monitored using wearable technology and home health monitoring using IoT devices. |
| 15 | Gupta et al. [70] | / | | | | When notified that they are at risk of having a heart attack, a patient must have a smartphone to receive a message or email. | The patient and the registered user will be alerted in time with the aid of IoT, sparing them from suffering an unexpected heart attack. | Results obtained demonstrate that the proposed method is capable, of producing an accuracy of 82%. |
| 16 | Bansal and Gandhi [115] | | / | | | Use conductive ECG electrodes from Carbon nanotubes | The information obtained must be transmitted to the doctor via his phone | The patient's life is saved after the nurse, guardian, or family member |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | or tablet so that the patient can be instantly advised of a treatment | who is caring for him receives the results via a smart device and gives him temporary relief |
| 17 | Chandurkar et al. [116] | / | / | | | Integrating mobile computing technologies with healthcare systems | Aid in reducing the death rate from heart attacks in rural areas | Measuring a user's heart rate in the early stages can help detect any heart abnormalities and heart attacks |
| 18 | Zhang et al. [117] | / | | | | Only one person at one time can be monitored by Health-Radio | Non-invasive, contactless method for detecting MI that uses wireless sensors to detect irregular heartbeats | Health-Radio can achieve a median MI detection accuracy of 81.2% when the users are stationary and 66.5% when the user is not stationary |
| 19 | Bhagchandani and Augustine [118] | / | | | | The system contains a wrist wearable sensor that continuously records data and heartbeat | Simple to use and can prevent a heart attack or cardiac arrest | Tested on a small number of people and it is taking accurate patient body measurements and sending out alerts when it detects an emergency |
| 20 | Masood et al. [119] | / | | | | Need to wear a wristband all the time | Immediately alerts the concerned doctor when the sensing parameters go over the specified limits | More easily and cheaply establish real-time communication between a doctor and a patient |

A feature used in heart attack monitoring systems in the vehicle is shown in *Table 7*. Heart rate and ECG signal were highly used as a feature in the system. In the vehicle, the technologies that have been used are by using sensors and wearable devices. Sensors are attached to the seat, seat belt and steering wheel. However, there is no research on heart attack monitoring systems using image processing in the vehicle.

**Table 7** Analysis of features used in heart attack monitoring systems in the vehicle

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| 1 | Dineshkumar et al. [19] | / | | | | The heat sensor is in the driver's seat, and the heart rate sensor is attached to the seatbelt. | Affordable and easily marketable even to normal individuals. | To benefit middle-class people by making this technology available to conventional |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | | cars, low-end autos, and most truck drivers. |
| 2 | Chowdhury et al. [22] | | / | | | A driver needs to wear a chest belt. | Lower power consumption. | Accuracy for ST-elevation and T-wave inversion is 97.4% and 96.3% |
| 3 | Chaudhary and Selvakumar [79] | / | | | | An Internet connection is always needed. | IoT played a major role and collecting all the information from the sensors. | To prevent an accident due to human mistakes. |
| 4 | Abu-Faraj et al. [80] | / | | | | The measurement of blood pressure was excluded from this method since there is no non-intrusive, commercially available sensor that can monitor this important parameter. | A simple approach for detecting heart attacks. | The novelty of this device is in the automation of the tasks that a driver must perform in the case of such an emergency with the minimum amount of effort. |
| 5 | Singh et al. [81] | | / | | | The output's noise level depends on the fabric's thickness. | A trustworthy and affordable health monitoring system for drivers. | The sampled ECG data was successfully transmitted to a central web server, where it could be used by a doctor to monitor patient health or by central authorities to provide quick assistance in the event of an emergency. |
| 6 | Emarose et al. [83] | / | | | | The optical system that is used to measure the heart rate is installed in the steering wheel for continuous interface with the driver. | The vehicle switches to cruise control in the event of a cardiac arrest, and GPS is used to send the measured parameters to any nearby hospitals for rescue. | Accidents can be avoided since the car stops when the driver loses control. |
| 7 | Lee and Liu [84] | / | / | | | Both the safety belt and the smart steering wheel were equipped with pressure sensors. | The driver's physiological signals were observed by a smart steering wheel, which evaluated the data to assess the driver's health. | According to the test results, the proposed real-time driver health monitoring system can efficiently |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | | monitor the driver's level of alertness and a heart condition, or arrhythmia. |
| 8 | Nirbhavane and Prabha [85] | / | | | | Used Android technology and an internet connection are needed. | Can withstand any intense bodily action, like jogging, running, jumping, etc. | Alert messages with GPS position data were delivered by SMS or email, and the message may be successfully put on the Facebook wall of the respective user. |
| 9 | Sinnapolu and Alawneh [86] | / | | | | Used Apple watch only | Autopilot is employed as an assistance | The driver health monitoring system is successfully demonstrated by utilizing an apple watch and a particle electron controller in cases of serious and critical conditions. |
| 10 | Jowkar et al. [87] | / | | | | Limitations when using eyewear such as lenses, spectacles, etc. | A device that is economic, social, and sustainable. | The result is displayed together with the driver's BPM. |
| 11 | Fouad et al. [89] | / | | | | Limitations on the subject's movements to detect a face. | Utilizing a cheap camera that is easily integrated into the rearview mirror of a vehicle. | The processed and recorded resulting heart rate readings are compared to actual measures acquired using a pulse oximeter. |
| 12 | Kavitha and Perumalraja [103] | | / | | | Being wired to the Arduino microcontroller and having a Bluetooth shield attached makes the device inappropriate to wear. | Cost-effective. | Offers the drivers' community a complete solution and end-to-end communication. |
| 13 | Sinnapolu and Alawneh [104] | | / | | | The PPG sensor is placed at the ear, while the ECG sensor is positioned on the chest. | Utilizing (ECG) and (PPG) sensors, compare and assess heart rate and cardiac variability data for | To record heart rate and heart rate variability data while driving. |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | developing heart disease, stroke, or other emergencies. | |
| 14 | Yadav and Gowda [105] | / | | | | A heart rate sensor is built into the smart band. | Will enable elderly people to monitor their heart rate and alert emergency personnel if any heart abnormalities are detected. | Creating a system that can aid in reducing mortality and heart attack early detection. |
| 15 | Arppana et al. [120] | / | | | | The region of the image is transformed into a heartbeat signal using the independent component analysis method. | Can be used by drivers to prevent collisions or by manual labourers who work in. | Non-contact-based detection methods make it easier to measure HR with more reasonable accuracy. |
| 16 | Deepika and Shubangi [121] | / | | | | The threshold value for all sensors. | User-friendly wheel of steering. | Performed on real-time drivers with heart-related diseases |
| 17 | Kumari and Sarma [122] | / | | | | A heartbeat sensor is attached to a seat belt. | If an abnormal change in the heartbeat is detected, the car gradually reduces speed and stops itself by turning on the parking light. | Heartbeat sensors are used to continuously monitor the driver's heart rate and avoid accidents by using the IoT |
| 18 | Khan et al. [123] | / | | | | The pulse sensor is attached to the driver's finger. | Inexpensive and implementable in all automobile types. | Prevents accidents when a driver experiences drowsiness or a heart attack, and it connects with the user's mobile device to alert in the case of an emergency. |
| 19 | Kathirvelu and Arif [124] | / | | | | Employs a machine learning system to identify the heart rate and pulse of cardiovascular disease (CVD) patients while driving. | Machine learning models are capable of correctly diagnosing patients' diseases. | The result of the simulation reveals that the proposed method is more accurate than other methods. |
| 20 | Vyshnavi and Narendar [125] | / | | | | GSM technology is not stable for an alert system | If the heart rate is abnormal vehicle is stopped and an intimation is sent by use of GSM | If the person driving is in an extremely bad condition, information is provided to a |

| No | References | Approach features | | | | Limitation | Advantages | Result |
|---|---|---|---|---|---|---|---|---|
| | | Heart Rate | ECG | $SpO_2$ | Image | | | |
| | | | | | | | | hospital or family |

Various technologies used in heart attack monitoring systems have been analysed and summarised in *Table 8*. Numerous researchers used IoT technology for heart attack monitoring systems. IoT systems for monitoring heart attacks could potentially involve the use of wearable devices or other technology that track a patient's vital signs and send alerts to a healthcare provider or emergency services if they detect abnormalities that could indicate a heart attack. The other technologies are microcontrollers, sensors, smartphones, machine learning, GSM and GPS. To ensure that a heart attack monitoring system using IoT is effective, it is important to ensure that the wearable devices and other technologies are reliable and accurately track vital signs. It is also important to have a system in place for responding to alerts and providing appropriate medical care. The limitation, advantages and results of the approach technology also have been concluded in *Table 8.*

**Table 8** Analysis of technologies that have been used in heart attack monitoring systems

| No | References | Approach Technologies | Limitation | Advantages | Result |
|---|---|---|---|---|---|
| 1 | Banoth et al. [126] | Machine learning | Use recurrent neural network (RNN) and long short-term memory (LSTM). | Highly accurate at predicting heart problems, correlation with current advanced techniques. | 97.3% accuracy which can be higher than other systems. |
| 2 | Mary et al. [127] | IoT, Sensor | A heart rate sensor needs to attach to the body. | Reduces the risk of heart attack by allowing you to check it at home. | Aids for hospital monitoring systems and assistance a person at home. |
| 3 | Rahil et al. [128] | IoT, Cloud computing, Microcontroller | A user-friendly 3-lead sensor set is used to capture the patient's ECG data. | Portable, cost-effective and easy to use. | Successfully used in practice, demonstrating its potential value to a smart city environment. |
| 4 | Shihab et al. [129] | IoT, Machine learning | A system using RNN. | The proposed technology enables the doctor to prescribe to patients without being physically present. | According to the evaluation of the result, the proposed system can effectively identify heart disease. |
| 5 | Mamun et al. [130] | Sensors, fifth-generation (5G) Wireless communication | Need a 5G wireless communication network to operate the system. | If a medical emergency arises within a self-driving smart car, mainly children, the elderly, and individuals with physical disabilities will benefit. | Not only make people's lives safer but also aids in managing serious health problems. |
| 6 | Anjana et al. [131] | Wearable devices, IoT | The elderly need to wear wearable devices. | To identify the problem earlier to reduce the number of heart attack deaths. | The proposed system is user-friendly, dependable, and affordable. |
| 7 | Giri et al. [132] | IoT, Sensor | IoT advancements must be included to allow patients with serious conditions to receive | It is simple to monitor the patient's pulse at home. | Determine heart failure by monitoring the pulse using IoT |

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| | | | appropriate treatment. | | |
| 8 | Khamitkar and Rafi [133] | IoT, Bluetooth | Leverages the capabilities of a heart rate sensor to collect data. | The system is adaptable, reliable and secure. | The system's ability to detect and read the user's heartbeat rate allowed for accurate experimental findings to be acquired. |
| 9 | Buthelezi et al. [134] | IoT, Sensor | The real-time reading transmission to the mobile application and online dashboard was dependent on the internet being accessible. | Utilised low-cost devices (such as sensors that can rapidly and simultaneously deliver diagnosis results for hearing problems, headaches, heart rate, and body temperature). | According to the results, only a small percentage of persons had readings that were off by 2-3%, which revealed an accuracy rate of 90%. |
| 10 | Sarmah [135] | IoT, Deep learning | This system uses deep learning modified neural network (DLMNN) which is developed in the JAVA working platform. | The heart disease of the patient can be predicted more precisely using this IoT-focused DLMNN classifier. | Compared to existing algorithms, the estimated experimental results indicate improvement. |
| 11 | Darmawahyuni and Nurmaini [136] | Deep learning | The LSTM algorithm's characteristic does not require independent and identically distributed (IID) data. | Deep learning will enable classifiers to learn without the need for human involvement. | The performance of the classifier is good. |
| 12 | Ray and Ray [137] | IoT, Sensor, Cloud Computing | Since the data is always end-to-end encrypted, the time of transmission might need to be compromised, which would cause delays in the presence of a real-time monitoring system. | Easily accessible and secured. | Measure the accuracy of the result. |
| 13 | Badhon et al. [138] | Sensor, Microcontroller | The ESP8266 module is not secure from cyberattacks. | To assist the patient, the doctor can remotely access the patient's heart readings on the website. | Every five seconds, anyone in the world can keep an eye on a patient who is prone to heart problems. |
| 14 | Gurjar and Sarnaik [139] | IoT, Sensor, Microcontroller | Monitoring of both temperature and heart rate using a single device. | Portable and affordable system. | Will aid in the early diagnosis of heart attacks and a decrease in mortality. |
| 15 | Mihiranga et al. [140] | IoT, Machine learning, Smartphone | Mobile phones are always connected to Wi-Fi | Can forecast the possibility of a heart attack using a set of established risk factors. | To decrease the number of heart patients who pass away from delayed treatments. |
| 16 | Kaviya and Suresh [141] | IoT, Sensor, Machine learning, GSM, GPS | All sensors must be attached to the user. | The system is portable and dependable. | The method enables earlier MI identification, preventing the |

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| | | | | | need for unnecessary medical treatment. |
| 17 | Sethuraman et al. [142] | IoT, Sensor, Microcontroller, GPS | Message queuing telemetry transport (MQTT) protocol is not easy to implement. | Uses a local server to offer minimal latency, security, and privacy. | Through the real-time monitoring system, the nurses or the on-call doctors at the hospital can keep an eye on the patient's heart rate on the serial monitor. |
| 18 | Patil and Chaware [143] | IoT, Sensor | Processing power for NodeMCU is weaker. | Easy to use and less expensive. | Wireless heart monitoring system for patient monitoring at any time and location. |
| 19 | Raihan et al. [144] | Smartphone | Lipid profile and blood pressure measurements are required. | Raises awareness of heart attack risk factors and attempts to reduce them. | The proposed method's sensitivity and accuracy were 89.25% and 76.05%, respectively. |

## 5.Discussion

This paper discusses technologies of heart attack monitoring systems at hospitals, at home and in the vehicle. Besides, we also explained features like heart rate, ECG, $SpO_2$ and image properties that are typically used by several researchers for heart attack monitoring. The following are the responses to the research questions for this paper:

RQ1. What are the technologies that have been used for heart attack monitoring systems?

There are various types of technologies worldwide that have been used for heart attack monitoring systems. The technologies are IoT, smartphones, sensors, Bluetooth, wearable devices and machine learning. All these technologies have their virtues and advantages. Typically, to develop a smart heart attack monitoring system, a combination of two or more technologies was used. Some heart attack monitoring systems were produced from a combination of wearable devices, sensors and IoT. A monitoring system is more reliable and accurate with all these kinds of combinations of technologies. IoT is a current technology nowadays. Rapid advancements in the IoT, cloud computing and Internet-based platforms for medical monitoring and management give hospitals and care facilities new opportunities to improve access to heart attack monitoring systems.

RQ2. Are there any image properties features that have been used for heart attack monitoring systems?

From our study, many features have been used for heart attack monitoring systems. The features are heart rate, ECG, $SpO_2$ and image properties. Heart rate and ECG are commonly applied as a feature in heart attack monitoring systems. There is limited work on image properties for heart attack monitoring systems.

RQ3. What are the challenges for heart attack monitoring systems?

These challenges have been identified by our study on technologies for heart attack monitoring systems which have been explained in this paper. The cost aspect is one of the challenges in heart attack monitoring systems. For heart attack monitoring systems at home, a camera is needed to be installed in the house. The camera is one of the technologies for heart attack monitoring systems. Camera installation is needed to cover up the full area of the house. It is very expensive to install more than one camera in the house. Likewise in the hospital, heart attack monitoring systems are costly on the payment of high-speed internet usage. The internet usage at the hospital must always be in full coverage to ensure the data of the patients and alert systems are safe and ready to use at any time. For heart attack monitoring

systems in vehicles, the technologies of sensors and microcontrollers are important to ensure that the measured parameter values are accurate and reliable. The cost of the sensors and microcontroller is also high. Other challenges for heart attack monitoring systems are to develop a system by using an image processing approach. Technology on camera is used for this approach. The camera will capture multiple images of a person's behaviours for further processing. That will be challenging to capture the image in multiple postures. More focus is needed on various postures and behaviour of the person which has chest pain symptoms of heart attacks. The challenges also occur if the system is used in real-life applications. Real-life applications must consider the ability of the heart attack monitoring system to detect the occurrence of heart attack symptoms. Besides, data security, privacy issues and power management of the systems also become the biggest concerns of people. The protection of data from illegal access, use, disclosure, disruption, alteration, or destruction is referred to as data security. Data security is crucial since it aids in preserving the privacy, accuracy, and availability of data, all of which are necessary for the heart attack monitoring system to operate effectively. Concerns over data collection, use, and disclosure of personal information by users or heart attack patients are referred to as privacy issues. Because it impacts patients' independence, autonomy, and dignity and is crucial for the protection of patient rights and liberties. The process of controlling and optimising the usage of power in a system for monitoring heart attacks is known as power management. Power management is crucial for ensuring that systems and devices can function effectively and efficiently while also saving energy and cost.

The current technology and a feature used in heart attack monitoring systems have been discussed in *Table 9*. *Table 9* shows the comparative analysis of features and technologies in the current year. Heart rate and ECG becomes the most popular features that have been used for heart attack monitoring systems. Besides that, there are many latest technologies used in the heart attack monitoring systems such as IoT, sensors, machine learning, deep learning, wearable device and microcontroller.

**Table 9** Comparative analysis of features and technologies for current heart attack monitoring systems

| No | References | Features | Technologies | Result | Limitation |
|---|---|---|---|---|---|
| 1 | Sahil et al.[145] | Heart rate | IoT | Rapid alerting system for heart attack and seizure sufferers. | Needs to wear the sensor on his fingers using the grove provided. |
| 2 | Yusuf et al.[146] | Human activity recognition | IoT, Wearable devices, Neural network | High accuracy of classification | Users need to wear a wristband all the time. |
| 3 | Sethi et al.[147] | Heart rate | IoT, Sensor | Hospital nurses or on-call doctors can remotely examine the patient's heart rate. | The pulse sensor only reports a BPM. |
| 4 | Haritha et al.[148] | Heart rate | IoT, Sensor, Microcontroller | Uses the internet to keep track of patient health statistics and promptly save lives. | Require constant internet access. |
| 5 | Munagala et al.[149] | Heart rate, blood pressure, | IoT, Machine learning | More accurate in predicting heart disease. | Require continuous access to the Internet |
| 6 | Qtaish and Al-Shrouf[150] | ECG | IoT, Sensor | Can aid in the early detection of heart conditions. | Monitoring of the ECG for a brief period. |
| 7 | Kanumuri et al.[151] | Heart rate | IoT, Sensor | Patients will receive the appropriate notifications via email and the internet if any abnormalities are found. | ECG sensors are susceptible to noise. |
| 8 | Mamun[152] | ECG | Sensor, Machine learning | Effectively identify elevated ST segments and make diagnoses | To increase the accuracy, further research must be done to identify more ECG features that are comparable to MI. |
| 9 | Rizwan et al.[153] | 13 features from the | Machine learning | With an accuracy of 90.16% and a recall of 87.09%, the K-Nearest Neighbor | Precision, F1-Score, and |

| No | References | Features | Technologies | Result | Limitation |
|---|---|---|---|---|---|
| | | online dataset. | | algorithm is the best method. | accuracy were all greatest for K-Nearest Neighbor, but the recall was lower. |
| 10 | Mazhar et al.[154] | Heart rate, ECG | Fuzzy logic, Sensor | Improves performance in determining proper heart disease risk levels and completes heart disease patient treatment owing to the doctors' shortcomings. | The input parameter data are obtained independently from one another. |
| 11 | Negi and Bisht[155] | Gender, age, chest pain, etc. | Machine learning | With an accuracy rate of 78%, KNN is the most reliable algorithm for heart attack prediction. | More machine learning models are required for accurate result. |
| 12 | Janaranjani et al.[156] | Patient data about coronary disease | Artificial intelligence | In comparison to other algorithms, the decision tree obtains the greatest prediction accuracy of 99.5% with the quickest rate of exactness. | Analysing unprocessed clinical data. |
| 13 | Saxena et al.[157] | 124 features that constituted the disease's cardinal symptoms, not only physiological signs of heart attacks. | Machine learning | The most accurate algorithm is the support vector machine method, which has a 95.15% of accuracy. | Inability to accurately visualise the different heart attack prediction patterns. |
| 14 | Ahmed et al.[158] | Image | Deep learning | Attained a 92% accuracy in the infarct classification. | Compare performance with other pre-trained models. |
| 15 | Zhu and Goldsztein[159] | 13 features from each patient | Machine learning | The model is 90% accurate in predicting whether a patient might suffer a heart attack. | The addition of new features can increase accuracy. |

**Limitation**

In this paper, we focused only on heart attack monitoring systems at hospitals, at home and in vehicles. The study is about a technology and a feature used that has been developed by previous researchers that reported globally and analysis of these attacks.

A complete list of abbreviations is shown in *Appendix I.*

## 6.Conclusion and future work

Many research studies have been published on ECG, heart rate and $SpO_2$ features by researchers worldwide. However, the studies on technologies for heart attack monitoring system in vehicle using image processing remains limited. This paper reviews the features that have been used by several researchers on heart attack monitoring systems at the hospital, at home and in the vehicle. A review of research papers shows that ECG, heart rate and $SpO_2$ features have been successfully applied to heart attack monitoring systems. There is limited research on image features for automatic heart attack monitoring systems at the hospital, at home and in the vehicle. In our future works, we will use image processing to monitor a heart attack in the vehicle. We will develop a heart attack monitoring system that focused on the driver's behaviour in the vehicle. An image property will be collected by using DashCam which is located in the vehicle. The research specialized in chest pain symptoms among a driver. Matlab software will be used to process the image properties.

When a heart attack occurred, drivers will be in various postures of the body at the driver's seat. For future work, we also will cover multiple postures of the body such as sitting back, lying down and supine. Next, we will develop an alert system using IoT. This

system will alert a medical professional if a person is suffering from a heart attack. Besides, we also will design a system that will be used for real time applications. A combination of driver's behaviour and face detection using image processing also will be developed for heart attack monitoring systems.

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## Conflicts of interest

The authors have no conflicts of interest to declare.

## Author's contribution statement

**Rohana Abdul Karim:** Conceptualization, supervision, revised the article for critical intellectual content and approved the final draft of the manuscript. **Noraizan Ibrahim:** Conceptualization, investigation, performed the analysis, writing the original draft and editing the manuscript. **Nurul Wahidah Arshad:** Investigation, supervision and review of the original draft of the manuscript.

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## Appendix I

| S. No | Abbreviation | Description |
|---|---|---|
| 1 | ECG | Electrocardiogram |
| 2 | $SpO_2$ | Oxygen Saturation |
| 3 | PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| 4 | IC | Inclusion Criteria |
| 5 | EC | Exclusion Criteria |
| 6 | MI | Myocardial Infarction |
| 7 | WSN | Wireless Sensor Network |
| 8 | PPG | Photoplethysmography |
| 9 | IoT | Internet of Things |
| 10 | Wi-Fi | Wireless Fidelity |
| 11 | GSM | The Global System for Mobile Communications |
| 12 | GPS | Global Positioning System |
| 13 | BPM | Beats Per Minute |
| 14 | SMS | Short Message Service |
| 15 | RNN | Recurrent Neural Network |
| 16 | LSTM | Long Short-Term Memory |
| 17 | 5G | Fifth-Generation |
| 18 | DLMNN | Deep Learning Modified Neural Network |
| 19 | AF | Atrial Fibrillation |