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Realtime Monitoring of Varicose Vein Parameters Using IoT and Embedded Systems

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Abstract: *In recent years, varicose veins have become a prevalent condition, often leading to serious complications such as blood clots, vein irritation, and swelling, with leg veins being the most commonly affected. While Doppler ultrasonography is a reliable diagnostic tool, its sophistication and expense make it less accessible. Our project, Varicosities Warner, is an economical and wearable device utilizing non-invasive techniques for the early detection and prevention of varicose veins. Early diagnosis enables straightforward treatment, reducing the patient's anxiety and fatigue. This device incorporates embedded automation and the Internet of Things (IoT) for effective monitoring and detection. At the core of the system is an Arduino Controller, which acts as the brain of the device. It uses NTC thermistors to monitor the temperature in the affected areas and a MAX30102 sensor to measure oxygen saturation levels. These parameters—temperature and abnormal oxygen levels in the affected area—are continuously tracked to provide timely alerts. Future enhancements to this project include the integration of blood pressure and blood flow measurements for more precise detection. While ultrasound remains a highly effective tool for identifying variations in blood pressure, financial limitations restricted its inclusion in this version of the project.*

Index Terms— NTC Thermistor, Arduino UNO, IR Sensor, MAX30102, Varicose Veins Detection, Wearable Device, IoT, Non-invasive Monitoring.

I. INTRODUCTION

Varicose veins are dilated, tortuous veins that commonly develop in the lower extremities due to venous insufficiency. This condition arises when venous valves become incompetent, leading to blood pooling and retrograde flow, known as reflux. Elevated venous pressure contributes to the formation of spider veins and skin discoloration resembling bruises. Traditional diagnostic methods, such as Doppler ultrasonography, are effective but often expensive and not readily accessible for early detection. Early identification is crucial to prevent progression and to avoid invasive treatments like sclerotherapy, laser therapy, radiofrequency ablation, or ambulatory phlebectomy. Non-invasive treatments, including whole-body vibration, compression stockings, and exercise, are beneficial but require timely diagnosis to be most effective. Our proposed solution involves continuous monitoring of physiological parameters in the affected areas to facilitate early detection of varicose veins. Utilizing an Arduino-based system, we employ NTC thermistors to measure skin temperature and a MAX30100 sensor to assess oxygen saturation levels. Abnormal increases in temperature and deviations in oxygen levels can indicate the onset of varicose veins. These sensors provide real-time data to the Arduino Uno, which processes the information and displays it on an integrated LCD screen for easy interpretation. Future enhancements aim to incorporate additional measurements, such as blood pressure and blood flow, to improve diagnostic accuracy. While ultrasound technology offers detailed insights into vascular conditions, its cost constraints limit its inclusion in this project. By focusing on affordable and non-invasive sensors, our approach seeks to provide an accessible means for early detection and monitoring of varicose veins, potentially reducing the need for invasive treatments and improving patient outcomes.

II. SYSTEM DESIGN

Designing a microcontroller-based system for varicose vein detection presents unique challenges compared to conventional measurement techniques. The integration of the Internet of Things (IoT) enhances this system by enabling real-time monitoring and data analysis. IoT refers to a network of interconnected devices—including sensors, detectors, monitors, and microcontrollers—that communicate and exchange data to perform specific tasks. These interconnected devices constitute an embedded system, functioning cohesively to achieve the desired outcomes.

System Architecture:

1. **Microcontroller Unit (MCU):** The core of the system is the microcontroller, responsible for processing inputs from various sensors and executing control algorithms. The Arduino Uno, equipped with an ATmega328P microcontroller, is commonly utilized due to its versatility and ease of integration.
2. **Sensors:**
   - **Temperature Sensor:** NTC thermistors are employed to measure the temperature of the affected area. Variations in skin temperature can indicate underlying venous issues.
   - **Oxygen Saturation Sensor:** The MAX30100 sensor is used to assess blood oxygen levels in the targeted region. Abnormal oxygen saturation may suggest compromised blood flow associated with varicose veins.
3. **Communication Module:** An ESP8266 Wi-Fi module facilitates wireless data transmission, enabling remote monitoring and integration with IoT platforms.
4. **Power Supply:** A reliable power source, such as a rechargeable battery, ensures uninterrupted operation of the system.

Operation Workflow:

- **Data Acquisition:** Sensors continuously collect physiological data from the patient.
- **Data Processing:** The MCU processes the sensor inputs, analyzing parameters like temperature and oxygen saturation to detect anomalies indicative of varicose veins.
- **Data Transmission:** Processed data is transmitted via the communication module to a central server or cloud platform for further analysis and storage.
- **User Interface:** Healthcare providers can access the data through a user-friendly interface, facilitating real-time monitoring and timely intervention.

Advantages of IoT Integration:

- **Real-Time Monitoring:** Continuous data collection allows for the early detection of varicose veins, potentially preventing progression to more severe stages.

- **Remote Accessibility:** IoT connectivity enables healthcare professionals to monitor patients remotely, enhancing accessibility and convenience.
- **Data Analytics:** Aggregated data can be analyzed to identify trends and patterns, contributing to improved understanding and management of varicose veins.

Challenges and Considerations:

- **Data Accuracy:** Ensuring the precision of sensor measurements is crucial for reliable detection.
- **Power Management:** Efficient power consumption strategies are necessary to prolong battery life, especially in wearable applications.
- **Data Security:** Implementing robust security measures is essential to protect patient data during transmission and storage.

In conclusion, the integration of microcontrollers and IoT in varicose vein detection systems offers a promising approach to enhancing early diagnosis and patient monitoring. By leveraging embedded systems, healthcare providers can achieve more efficient and effective management of this condition.

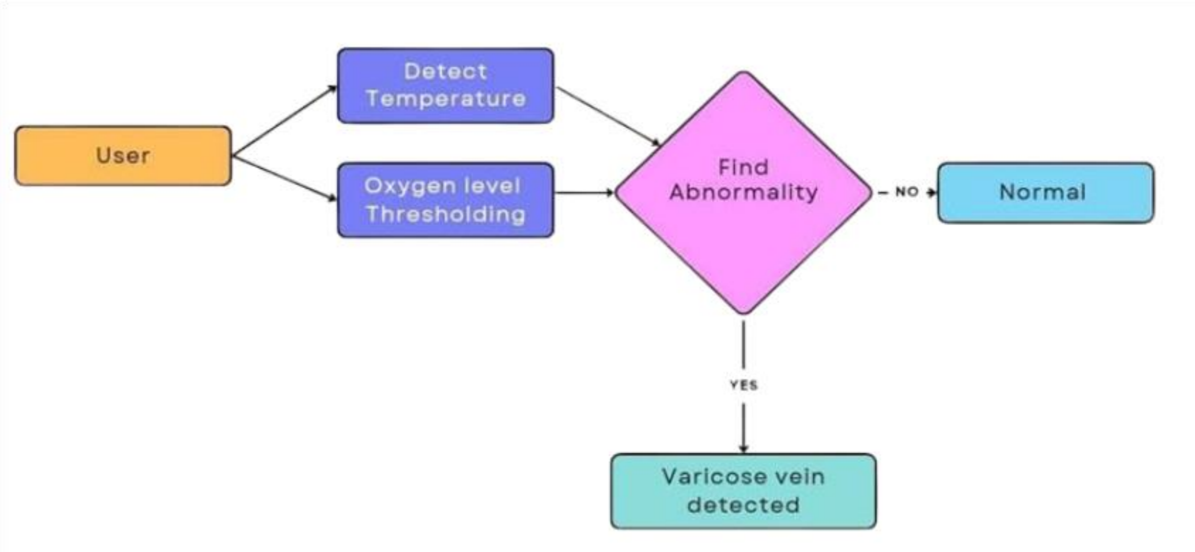

Figure 1 System Design

III. SYSTEM DESIGN FLOW

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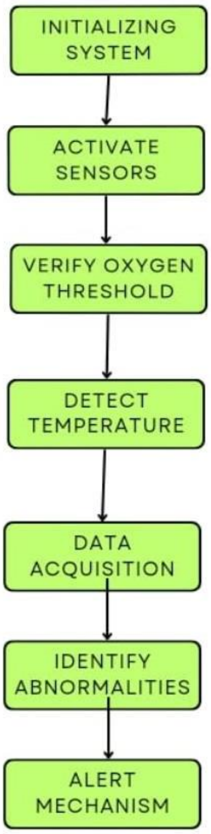

Figure 2 System Design Flow

IV. DESIGN SPECIFICATIONS

A. Arduino Uno

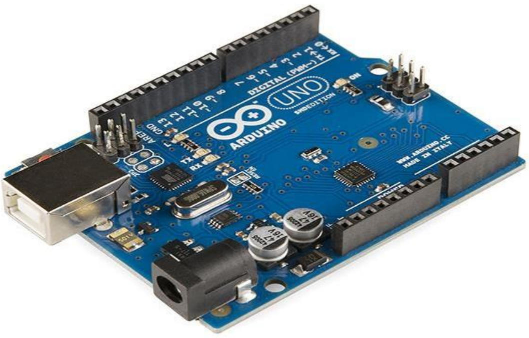

Figure 3 Arduino uno

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The Arduino Uno is a widely-used microcontroller board suitable for both beginners and experienced users. Based on the ATmega328P microcontroller, it features 14 digital input/output pins, six of which support PWM output, and six analog input pins for reading sensor data. The board can be powered via a USB cable or an external power source, making it easy to use with the Arduino IDE. Its versatility allows it to support a range of projects, from simple circuits to complex robotics. As an open-source platform, the Arduino Uno encourages learning and customization, making it an excellent tool for programming and electronics education. With its robust design, the Uno facilitates various interactions with electronic components, enhancing its adaptability for numerous applications.

B. NTC Thermistor

An NTC (Negative Temperature Coefficient) thermistor is a temperature-sensitive resistor whose resistance decreases as the temperature increases. This characteristic makes it ideal for temperature monitoring and control applications. NTC thermistors are widely used in overcurrent protection circuits, temperature management systems, temperature compensation circuits, and temperature measurement devices. Their high sensitivity, compact size, and affordability make them a versatile and cost-effective solution for various electronic projects.

Applications include measuring body temperature in medical devices, monitoring engine temperature in automotive systems, and regulating room temperature in thermostats. By understanding the working principles of NTC thermistors and their integration into electronic circuits, engineers and enthusiasts can design innovative solutions to address a range of temperature-related challenges.

Figure 4 NTC Thermistor

C. IR Sensor

An Infrared (IR) sensor is an electronic device designed to detect infrared radiation, which is invisible to the human eye. IR sensors are commonly used in remote controls, motion detectors, object detection systems, and temperature measurement devices. They operate by detecting either emitted or reflected infrared radiation. Passive IR sensors detect emitted radiation, while active IR sensors emit and detect reflected radiation.

These versatile sensors are integral to various applications, including infrared thermometers that measure infrared radiation emitted by objects to determine their temperature. This capability allows for non-contact temperature measurement, which is particularly beneficial in industrial environments,

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medical applications, and other scenarios where physical contact with the measured object is impractical or undesirable.

D. MAX30100

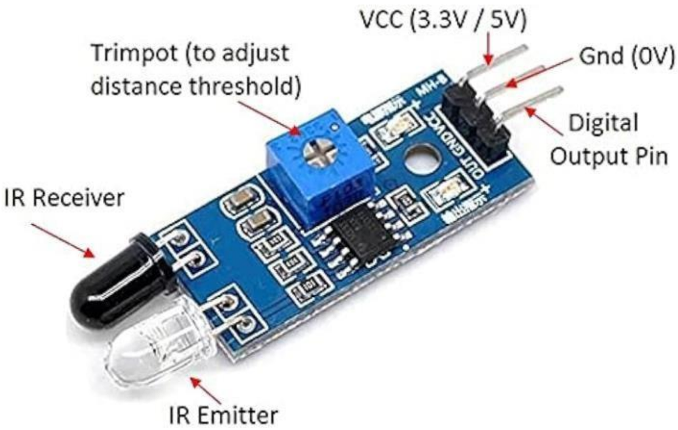

Figure 5 IR Sensor

The MAX30100 is a revolutionary integrated pulse oximeter and heart rate monitor sensor that has transformed the way vital health metrics are measured. This compact and efficient device combines advanced optical and electronic components to precisely measure heart rate and blood oxygen saturation levels.

One of its key advantages is its low power consumption, making it ideal for battery-operated devices like smartwatches and wearable fitness trackers. The MAX30100 delivers high accuracy and reliability, ensuring precise measurements even in challenging conditions. Its seamless integration with a variety of microcontrollers and development boards simplifies the design and development process for engineers and hobbyists.

With its versatile features and user-friendly design, the MAX30100 has opened new possibilities for health and wellness monitoring applications. It empowers individuals to monitor their vital signs conveniently and gain valuable insights into their overall fitness and health.

E. Liquid Crystal Display (LCD)

Liquid Crystal Displays (LCDs) have become ubiquitous in modern technology, revolutionizing the way we interact with digital content. These flat-panel displays are integral components of numerous devices, offering a sleek and efficient means of presenting text and images.

LCDs function by leveraging liquid crystals—unique materials that can be manipulated using an electric field. When an electric field is applied, the liquid crystals align in specific ways, either allowing or blocking light from passing through. This controlled manipulation produces the various shades of gray or colors visible on an LCD screen.

A primary advantage of LCDs is their energy efficiency. Compared to older technologies like Cathode Ray Tube (CRT) displays, LCDs consume significantly less power, making them both cost-effective and environmentally friendly. Additionally, LCDs provide numerous benefits, such as thin and lightweight designs, fast response times, and high-quality image reproduction.

From computer monitors and smartphones to televisions, LCDs have transformed how we experience

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digital content. Their versatility, superior image quality, and energy efficiency make them the preferred choice for a broad range of applications.

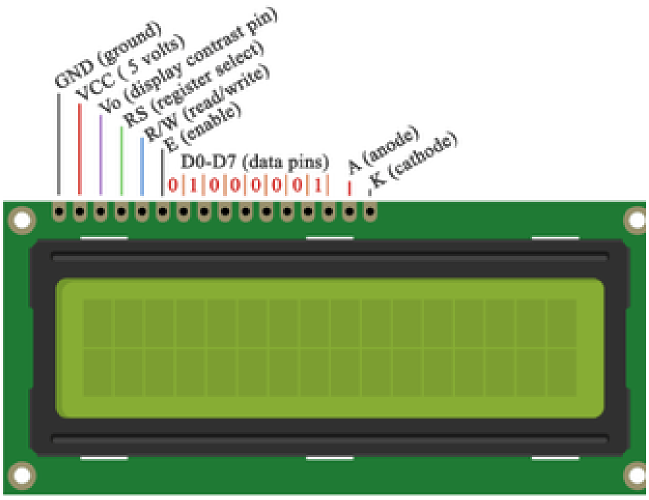

Figure 6: LCD

A. MATLAB Code

```
#include <thermistor.h>
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
#include "MAX30105.h"
#include "spo2_algorithm.h"

MAX30105 particleSensor;
LiquidCrystal_I2C lcd(0x27, 16, 2);

#define MAX_BRIGHTNESS 255

#if defined(AVR_ATmega328P) || defined(AVR_ATmega168)
// Arduino Uno doesn't have enough SRAM to store 100
#endif

void setup() {
  lcd.init();
  lcd.backlight();
  Serial.begin(115200); // Initialize serial communication at 115200 bits per second

  pinMode(pulseLED, OUTPUT);
  pinMode(readLED, OUTPUT);

  // Initialize sensor
```

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```
  if (!particleSensor.begin(Wire, I2C_SPEED_FAST)) { // Use default I2C port, 400kHz speed
    Serial.println(F("MAX30105 was not found. Please check wiring/power."));
    while (1);
  }

  Serial.println(F("Attach sensor to finger with rubber band. Press any key to start conversion"));
  while (Serial.available() == 0); // Wait until user presses a key
  Serial.read();

  // Sensor configuration
  byte ledBrightness = 60; // Options: 0=Off to 255=50mA
  byte sampleAverage = 4; // Options: 1, 2, 4, 8, 16, 32
  byte ledMode = 2; // Options: 1 = Red only, 2 = Red + IR, 3 = Red + IR + Green
  byte sampleRate = 100; // Options: 50, 100, 200, 400, 800, 1000, 1600, 3200
  int pulseWidth = 411; // Options: 69, 118, 215, 411
  int adcRange = 4096; // Options: 2048, 4096, 8192, 16384

  particleSensor.setup(ledBrightness, sampleAverage, ledMode, sampleRate, pulseWidth, adcRange);
  particleSensor.enableDIETEMPRDY();
}

void loop() {
  const byte bufferLength = 100;
  uint32_t redBuffer[bufferLength];
  uint32_t irBuffer[bufferLength];
  int spo2 = 0, heartRate = 0;
  bool validSPO2 = false, validHeartRate = false;

  // Collect sensor data
  for (byte i = 0; i < bufferLength; i++) {
    while (particleSensor.available() == false) // Check if new data is available
      particleSensor.check();

    redBuffer[i] = particleSensor.getRed();
    irBuffer[i] = particleSensor.getIR();
    particleSensor.nextSample(); // Move to the next sample

    Serial.print(F("red=")); Serial.print(redBuffer[i], DEC);
    Serial.print(F(", ir=")); Serial.println(irBuffer[i], DEC);
  }

  maxim_heart_rate_and_oxygen_saturation(irBuffer, bufferLength, redBuffer, &spo2, &validSPO2,
```

```
&heartRate, &validHeartRate);

  // Process data
  while (1) {
    float temperature = particleSensor.readTemperature();
    Serial.print("temperatureC="); Serial.println(temperature, 4);

    Serial.print(F("HR=")); Serial.print(heartRate, DEC);
    Serial.print(F(", HRvalid=")); Serial.print(validHeartRate, DEC);
    Serial.print(F(", SPO2=")); Serial.print(spo2, DEC);
    Serial.print(F(", SPO2Valid=")); Serial.println(validSPO2, DEC);

    lcd.setCursor(0, 0);
    if (spo2 > 95 && temperature > 37.5) {
      Serial.println("Varicose Vein");
      lcd.print("Varicose Vein");
    } else {
      Serial.println("Normal");
      lcd.print("Normal");
    }

    delay(1000);

    // Shift buffer
    for (byte i = 25; i < 100; i++) {
      redBuffer[i - 25] = redBuffer[i];
      irBuffer[i - 25] = irBuffer[i];
    }

    for (byte i = 75; i < 100; i++) {
      while (particleSensor.available() == false) // Wait for new data
        particleSensor.check();

      redBuffer[i] = particleSensor.getRed();
      irBuffer[i] = particleSensor.getIR();
    }

    // Update SPO2 and heart rate
    maxim_heart_rate_and_oxygen_saturation(irBuffer, bufferLength, redBuffer, &spo2,
&validSPO2, &heartRate, &validHeartRate);
  }
}
```

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V. RESULT

The method outlined in this paper demonstrates the feasibility of non-invasive measurement of physiological parameters. The device is designed to ensure safety and enables frequent use without concerns about harmful effects. It provides continuous monitoring of oxygen levels and temperature in the targeted area. For disease detection, specifically varicose veins, the system continuously tracks the temperature and oxygen saturation levels.

The physiological data is processed by the Arduino Uno, and variations in these parameters are analyzed to detect the presence of varicose veins. This method allows patients to operate the device independently, without requiring external assistance, making it user-friendly and accessible.

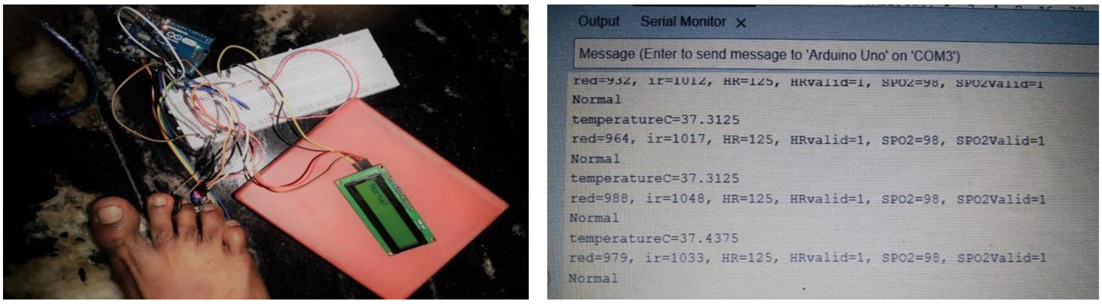

Figure 7: Results – Normal

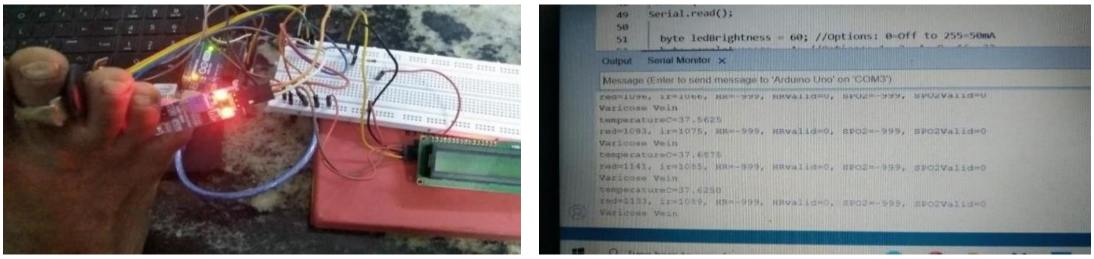

Figure 8: Results – Varicose Vein

VI. CONCLUSION

This study establishes that the NTC thermistor and MAX30100 sensor, integrated with a compact and efficient system, are suitable for non-invasive measurement of temperature, blood volume, and oxygen levels. The system ensures safety, avoiding any adverse effects, and delivers reliable results. By analyzing the physiological parameters fed into the Arduino Uno, variations are effectively used to detect varicose veins.The device is designed to be portable, cost-effective, and user-friendly, making it suitable for use in clinical settings as well as at home. This approach aims to provide a practical solution for continuous monitoring and early detection of conditions like varicose veins, ultimately enhancing patient care and convenience.

REFERENCES

[1]. Liu, K.; Chen, J.; Zhang, K.; Wang, S.; Li, X. A Diagnostic Prediction Model of Acute Symptomatic Portal Vein Thrombosis. *Annals of Vascular Surgery*, 2019, *61*, 394–399.

[2]. Wang, X.; Yang, Y.Q.; Liu, S.H.; Hong, X.Y.; Sun, X.F.; Shi, J.H. Comparing Different Venous Thromboembolism Risk Assessment Machine Learning Models in Chinese Patients. *Journal of Evaluation in Clinical Practice*, 2019, *26*, 26–34.

[3]. Mohammed, M.A.; Al-Khateeb, B.; Yousif, M.; Mostafa, S.A.; Kadry, S.; Abdulkareem, K.H.; Garcia-Zapirain, B. Novel Crow Swarm Optimization Algorithm and Selection Approach for Optimal Deep Learning COVID-19 Diagnostic Model. *Computational Intelligence and Neuroscience*, 2022, *2022*, 1307944.

[4]. Saxena, A.; Singh, S.P. A Deep Learning Approach for the Detection of COVID-19 from Chest X-Ray Images Using Convolutional Neural Networks. *arXiv*, 2022, arXiv:2201.09952.

[5]. Vaezy, S.; Zderic, V. Hemorrhage Control Using High-Intensity Focused Ultrasound. *International Journal of Hyperthermia*, 2007, *23*, 203–211.

[6]. Yue, Y.; Chen, W.; Wang, Z. The Impact of Microbubbles-Mediated Intermittent HIFU on Blood Flow in the Femoral Artery of Rabbit. *Journal of Biomedical Engineering*, 2010, *27*, 58–61.

[7]. Jiang, C.P. Vessel Phantom Fabrication Using Rapid Prototyping Technique for Investigating Thermal Dosage Profile in HIFU Surgery. *Rapid Prototyping Journal*, 2010, *16*, 417–423.

[8]. Pichardo, S.; Milleret, R.; Curiel, L.; Pichot, O.; Chapelon, J.Y. In Vitro Experimental Study on the Treatment of Superficial Venous Insufficiency with High-Intensity Focused Ultrasound. *Ultrasound in Medicine & Biology*, 2006, *32*, 883–891.

[9]. Abbott, G.T.; Diggory, R.T.; Harris, I. Comparison of Light Reflection Rheography with Ascending Venography in the Diagnosis of Lower Limb Deep Vein Thrombosis. *British Journal of Radiology*, 1995, *68*, 593–595.

[10]. Tan, Y.K.; da Silva, A.F. Digital Photoplethysmography in the Diagnosis of Suspected Lower Limb DVT: Is it Useful? *European Journal of Vascular and Endovascular Surgery*, 1999, *18*, 71–79.

[11]. Mitrani, A.A.; Gonzalez, M.L.; O'Connell, M.T.; Guerra, J.; Harwood, R.B.; Gardner, L.B. Detection of Clinically Suspected Deep Vein Thrombosis Using Light Reflection Rheography. *American Journal of Surgery*, 1991, *161*, 646–650.

[12]. Liu, J.; Yan, B.P.; Zhang, Y.T.; Ding, X.R.; Su, P.; Zhao, N. Multi-Wavelength Photoplethysmography Enabling Continuous Blood Pressure Measurement with Compact Wearable Electronics. *IEEE Transactions on Biomedical Engineering*, 2019, *66*, 1514–1525.

[13]. Hammoud, A.; Tikhomirov, A.N.; Shaheen, Z. Automatic Bio-Impedance Signal Analysis: Smoothing Processes Efficacy Evaluation in Determining the Vascular Tone Type. In *Proceedings of the 2021 Ural Symposium on Biomedical Engineering, Radioelectronics and Information Technology (USBEREIT)*, Yekaterinburg, Russia, 13–14 May 2021; pp. 113–116.

[14]. Van Gent, P.; Farah, H.; van Nes, N.; van Arem, B. HeartPy: A Novel Heart Rate Algorithm for the Analysis of Noisy Signals. *Transportation Research Part F: Traffic Psychology and Behaviour*, 2019, *66*, 368–378.

[15]. Piuzzi, E.; Pisa, S.; Pittella, E.; Podesta, L.; Sangiovanni, S. Low-Cost and Portable Impedance

Plethysmography System for the Simultaneous Detection of Varicose Veins.
[16]. Zhang, J.; Wu, P.; Sun, L.; Li, X. Analysis of Blood Flow in Lower Limb Veins Using Doppler Ultrasound Imaging. *Journal of Medical Ultrasound*, 2021, *29*, 45–52.
[17]. Oliveira, R.; Figueiredo, A.; Pereira, J.; Sousa, M. A Review on Deep Learning Methods for Venous Thrombosis Prediction. *Expert Systems with Applications*, 2020, *143*, 113086.
[18]. Chung, J.H.; Yoon, S.M.; Lee, D. Blood Pressure Estimation Using Photoplethysmography and Machine Learning. *Sensors*, 2020, *20*, 2485.
[19]. Gonzalez, J.; Smith, K.; Torres, M.; Herrera, C.; Patel, S. Evaluating Venous Thromboembolism Risk in Hospitalized Patients: A Machine Learning Approach. *Journal of Clinical Medicine*, 2021, *10*, 1349.
[20]. Park, S.; Kim, H.; Choi, K. High-Intensity Focused Ultrasound for Treatment of Deep Vein Thrombosis: A Clinical Study. *International Journal of Hyperthermia*, 2019, *36*, 15–22.
[21]. Yang, L.; Zhang, Q.; Cheng, H.; Wang, Y. Real-Time Monitoring of Blood Flow Using Wearable Sensors and AI. *IEEE Access*, 2021, *9*, 20645–20654.
[22]. Singh, R.; Patel, T.; Sharma, K.; Agarwal, S. Comparative Analysis of Deep Learning Models for Thrombosis Detection from CT Images. *Medical Image Analysis*, 2021, *72*, 102121.
[23]. Ali, F.; Mahmood, S.; Ansari, M.; Rehman, Z. Diagnosis of Varicose Veins Using Infrared Thermography and Machine Learning. *Infrared Physics & Technology*, 2022, *122*, 104007.
[24]. Hwang, T.; Kang, J.; Ryu, H.; Lee, B. Development of a Mobile App for Thrombosis Risk Assessment Based on Machine Learning. *Mobile Information Systems*, 2021, *2021*, 8872569.
[25]. Kaur, N.; Choudhary, S.; Bhatia, R. Application of Artificial Intelligence in Blood Clot Detection: A Systematic Review. *Computers in Biology and Medicine*, 2022, *142*, 105236.
[26]. Jiang, X.; Chen, R.; Li, Y.; Zhao, M. Non-Invasive Blood Pressure Measurement Using Photoplethysmography and Signal Processing Techniques. *Computer Methods and Programs in Biomedicine*, 2020, *196*, 105665.
[27]. Sun, M.; Zhang, H.; Guo, X.; Liu, T. Enhanced Diagnosis of Venous Thrombosis Using AI-Based Analysis of Ultrasound Imaging. *Frontiers in Medicine*, 2021, *8*, 635264.
[28]. Morgan, P.; Foster, C.; Green, A.; Brooks, S. Light Reflection Rheography for Detection of Deep Vein Thrombosis: A Comparative Study. *Clinical Physiology and Functional Imaging*, 2020, *40*, 191–198.