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# AI-Integrated Diagnostic System for Varicose Veins using Deep Learning and Health Signal Inputs

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***Abstract*— Varicosities is a prevalent problem which belong to the adults category involved in prolonged standing and sitting conditions. Doppler ultrasonography and visual observation, are traditional techniques to diagnose varicose veins which demand the expertise of qualified medical professionals, and the high price of diagnostic technology presents a nearly insurmountable barrier to healthcare in developing countries. Thus this study proposed a novel idea of Intelligent Varicose Veins detection system. This system uses imaging and real-time health signals to provide affordable intelligent diagnostic solutions based on varicosity features and their relevant health signals. The deep learning model comprises of a hybrid framework combining YOLOv9 and EfficientNet- B0.The dataset consisted of about 2500 annotated leg images with above 94% accuracy and mean Average Precision of 89%. Different health parameters such as leg movement, pose and blood flow rate are measured through IMU and PPG/Doppler sensors. With efficient IoT device using ESP32-S3 Microcontroller, collected data is transmitted through a FastAPI and a React.js is used for vein diagnosis visualization and report generation. In Addition a cloud deployment model offers unparalleled flexibility, scalability, robust security, and seamless remote access.**

***Keywords*— CNN, YOLO, EfficientNetB0 architecture, Medical Image Analysis, varicose detection.**

## I. INTRODUCTION

Pooling of blood in the veins cause due to weaken or damaged of venous valve maintained unidirectional blood flow toward the heart. Visibly twisted, enlarged, and swollen blood vessels is varicose veins which is common lower-limb vascular issue. Venous statis ulcers, Venous thromboembolism, and Chronic venous disease are severe complication if not treated properly. Doppler ultrasonography and venography are traditional methods but are expensive and required trained person for early detection. High diagnostic cost and lack of medical facilities are main causes of people were undiagnosied. Early diagnosis and continuous monitoring is possible because of Internet of Thing and evolution of Artificial Intelligence. Deep learning algorithm such as CNN provides Automated and accurate disease detection in medical image analysis. Real time data is acquired with biomedical sensors. For remote and resource-limited areas AI and IoT technologies integrated system forms a powerful foundation. This system perform precise, non-invasive varicose vein detection and monitoring. The proposed AI-Integrated Diagnostic System combines hybrid diagnostic platform of deep learning based image analysis and sensor based IoT system.

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The aims of proposed system is to bridge the gap between accessibility and diagnostic capabilities. Physiological parameters are measured by photoplethysmography (PPG) module and an inertial measurement unit (IMU) .Camera or mobile device is used to capture leg images. This model is capable of proving high accuracy with YOLOv9 deep-learning architectures for detection and EfficientNet-B0 for classification. The system architecture provides core communication hub between the AI and IoT components. It includes a secure cloud-based backend developed using FastAPI, MongoDB database is used for collection of sensor data. To built Web interface React.js is used at front end.

## II. LITERATURE REVIEW

Diagnosis, treatment, and prediction in varicose vein disorders played a key role for both traditional clinical methods and modern deep learning and artificial intelligence systems.
K. Haritha et.al. reviews papers for existing systems of varicose veins diagnosis and treatment by both traditional and technology-driven approaches. This review paper traced on invasive and noninvasive therapies. It emphasizes on effective solution for detection of varicose veins.[1]
The paper focus on diagnosis and treatment of varicose veins. With treatment Life quality can improved and also varicose veins risk can reduced. It discusses various types of treatment to improve quality of life and risk. Risk of Varicosities can reduce by Yoga or exercise and fruits vegetables consumption .Also various surgical treatment minimize complications.[2]
Ultrasound and thermography data utilized for model classifier by Lin et.al. It is an additional multimodal approach. With combined various imaging techniques accuracy is improved in classification. [3].
Lee and Park focused on distinction between CNN and ViT models. Out of which Emerging deep learning model was Vision Transformers because of superior feature extraction capabilities [4].
Faster R-CNN deep learning model is proposed by T. Sriranjani et.al. Real time Integration is taken for varicose veins detection. Accuracy is improved by findings affected leg region in image. This model provide accurate diagnosis as compared to traditional method. Object detection models is used for vein disorder.[5]
Fu S, Chen et.al implemented a prediction system to specify patients late physical mobility after varicose vein surgery. Data of total of 312 patients was used for study. These are divided as a case group (delayed early ambulation) and a control group (normal early ambulation).Here logistic regression algorithm is implemented to evaluate performance. Based on prediction model distinguishes The model effectively distinguishes patients at risk.[6]
Summia Parveen et.al. proposed early detection varicose vein AI based application .To detect and classify varicose veins from leg images model utilizes VGG Net, The system provides improved classification performance and detection accuracy by incorporating multilingual resources .Advance patient-centered care is main aim of model.[7]
Model proposed by Barulina, M.et.al. automatically classify chronic venous disease by Image based analysis. Dataset of 10,618 images of legs are used. To classify model researcher worked on ResNet50 Convolutional Neural Network, DeiT Vision Transformer and custom vit-base Configurations. Best performance parameters are showed by Resnet50.[8]
This research by Li B, Eisenberg et.al. used 33,924 varicose veins treatment patients dataset with 5,619 experiencing lack of clinical improvement at 1 year. Various machine learning model is applied to predict the result. High predictive accuracy (0.94) achieved by XGBoost model. Logistic regression showed comparatively less performance.[9]
Pugalenthi, L et.al. focused on computer vision techniques. Intelligent computing for varicose vein management is used to analyze clinical data and medical images. This system gives disease classification and prediction based on patterns, history, symptoms. It focused on early detection, treatment planning with improved accuracy. Varicose vein management is enhanced with AI.[10]
The literature illustrates a range of approaches from Machine learning models to IoT enabled diagnostic systems and varicose veins detection, diagnosis, and severity classification are done by Machine learning and deep learning techniques. Logistic regression and XGBoost Predictive provide efficiency. With this advancement intelligent varicose vein management systems enable more accurate, automated.

## III. METHODOLOGY

The flow of the model design methodology is given below.

*A. Data Acquisition*

Dataset comprising human legs normal and varicose vein conditions, along with blood flow and leg movement signals using IoT sensors.2500 legs images are used.

*B. Preprocessing*

Normalization with size(416 * 416 pixels), noise removal using Gaussian blur and histogram equalization are used for preprocessing. Labeling of image is done as Normal or affected with severity levels.

*C. Model Training*

Image identification of varicose vein is implemented by YOLOv9 algorithm. Feature extraction is found with EfficientNet-B0. A deep learning is trained to identify venous patterns and fine-tuned using labeled image data.

*D. Hardware integration*

PPG sensor and IMU sensor are used to collect health related parameters such as blood flow and leg movement. ESP32 Iot based system is used for cloud interaction.

*E. Software Platform*

A Processed Information is stored in MongoDB database with FastAPI backend architecture. User can upload image with A React.js-based web interface.

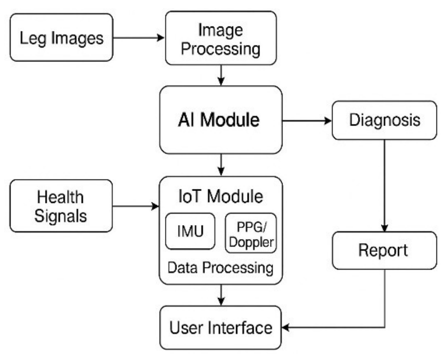


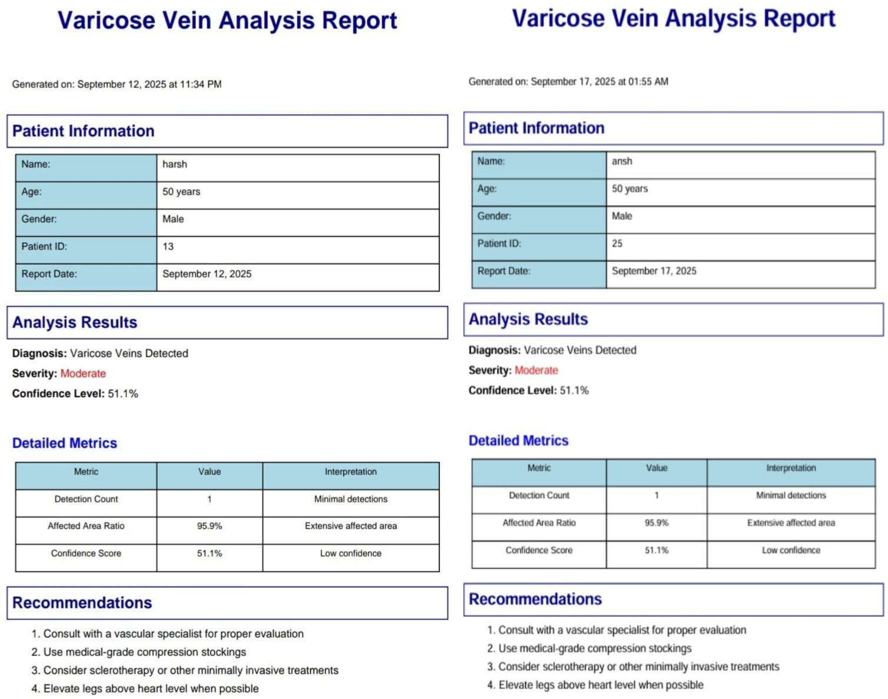

Figure 1: AI Integrated Varicose veins Diagnostic System

## IV. Results and Discussion

The system was tested for both affected and Normal cases images. Figure 2a shows a healthy leg with no vericose sign. Figure 2b displayed affected area on the lower limbs, annotated with square box. Figure 3 presents Proposed web-based interface system. Case studies on Early detection of mild varicose veins, Moderate varicose veins and Severe varicose veins with Abnormal Blood Flow and Low Blood Flow are done.

(a) Normal Lower Limbs Without Varicose sign (b) Varicose Vein Regions Annotation

Figure 2: Asymptomatic Vs Symptomatic Varicose Veins



## Varicose Vein Analysis Report

Generated on: September 12, 2025 at 11:34 PM

### Patient Information

| | |
|---|---|
| Name: | harsh |
| Age: | 50 years |
| Gender: | Male |
| Patient ID: | 13 |
| Report Date: | September 12, 2025 |

### Analysis Results

**Diagnosis:** Varicose Veins Detected
**Severity:** Moderate
**Confidence Level:** 51.1%

**Detailed Metrics**

| Metric | Value | Interpretation |
|---|---|---|
| Detection Count | 1 | Minimal detections |
| Affected Area Ratio | 95.9% | Extensive affected area |
| Confidence Score | 51.1% | Low confidence |

### Recommendations

1. Consult with a vascular specialist for proper evaluation
2. Use medical-grade compression stockings
3. Consider sclerotherapy or other minimally invasive treatments
4. Elevate legs above heart level when possible

## Varicose Vein Analysis Report

Generated on: September 17, 2025 at 01:55 AM

### Patient Information

| | |
|---|---|
| Name: | ansh |
| Age: | 50 years |
| Gender: | Male |
| Patient ID: | 25 |
| Report Date: | September 17, 2025 |

### Analysis Results

**Diagnosis:** Varicose Veins Detected
**Severity:** Moderate
**Confidence Level:** 51.1%

**Detailed Metrics**

| Metric | Value | Interpretation |
|---|---|---|
| Detection Count | 1 | Minimal detections |
| Affected Area Ratio | 95.9% | Extensive affected area |
| Confidence Score | 51.1% | Low confidence |

### Recommendations

1. Consult with a vascular specialist for proper evaluation
2. Use medical-grade compression stockings
3. Consider sclerotherapy or other minimally invasive treatments
4. Elevate legs above heart level when possible

Figure 3: Patients Report

The system shows effective performance in separating varicose and healthy cases, achieving accuracy of 94 %. System approach Performance metrics with 89% Precision ,90% Recall and 89% F1 Score.

TABLE I: EVALUATION METRICS

| Parameters | Value (%) |
|---|---|
| Precision | 89 |
| Accuracy | 94 |
| Recall | 90 |
| F1 Score | 89 |

## V. CONCLUSION

Faster clinical decision making is possible with precise and fast varicose veins identification by proposed system. IoT-based system consists of image processing , PPG ,IMU sensors with ESP 32 Microcontroller. To analyze leg images hybrid deep learning architecture is utilized. System comprises of object detection YOLOV9 with EfficientNetB0 to get high diagnostic performance. 89% Precison and 94% accuracy is achieved by this system. Sensors provides health related parameters and this real time data are transmitted through ESP32-based setup with a FastAPI. MongoDB database is used for data storage and Restnet.js web interface which supports image upload and automated varicose veins report generation. This idea improved accessibility, remove medical expertise need, less costly as compared to traditional doppler ultrasound method. This approach enables varicose veins early detection and diagnosis support. Further Cloud based deployment approach is used in remote area where healthcare is lacking. Future work focuses on dataset expansion, scars and tattoos evaluating situations to boost model performance. To enhance clinical reliability integrating doppler validation with continuous monitoring may work.

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