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# Recommendation System for Stroke Risk Prediction using Machine Learning Approaches

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***Abstract*— Early detection and prevention of strokes are crucial for lowering morbidity and death. To evaluate stroke risk, this study uses predictive modeling, which includes clinical biomarkers, lifestyle factors, and demographic data. Machine learning techniques including logistic regression, gradient boosting and random forest are used to a variety of datasets. The result is a personalized risk score, which encourages high-risk patients to seek medical attention. Individual risk profiles are used to develop customized interventions such as medication, lifestyle changes, and exercise suggestions. This proactive method promises to reduce stroke incidence while improving health outcomes, potentially transforming early detection and preventive strategies.**

***Index Terms*— Stroke Risk Prediction, Logistic Regression, Gradient Boosting, Random Forest.**

## I. INTRODUCTION

Stroke continues to pose a considerable global health challenge, causing to significant morbidity, death, and social consequences. Despite developments in the field of medicine and technology, urgency of addressing this issue is underscored by projections indicating a growing incidence of stroke due to aging populations, urbanization, and changes in lifestyle factors such as diet and physical activity patterns. Furthermore, disparities in stroke incidence and outcomes persist across geographic regions and socioeconomic strata, highlighting the need for equitable access to preventive interventions and healthcare services.

In last years, there has been a growing identification of the importance of early identification and preventive strategies in mitigating the impact of stroke. Timely intervention, including lifestyle modifications, medication adherence, and medical interventions such as thrombolysis and endovascular therapy, can significantly be helpful. Traditional risk assessment approaches for stroke, which typically rely on clinical risk scores derived from demographic, clinical, and laboratory data, have limitations in terms of accuracy and precision. These scoring systems, offer insightful information about the overall risk profile of an individual but may fail to capture subtle interactions among risk factors or account for individual variations in susceptibility to stroke. As a result, there is increasing interest in exploring alternative approaches to stroke risk prediction that leverage emerging technologies and analytical methods. The machine learning focuses on creating algorithms that can analyze data, draw conclusions, or decisions, holds promise for enhancing stroke risk prediction.

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Neural networks, support vector machines, decision trees, random forests, and other machine learning approaches are adept at managing intricate, high-dimensional datasets and uncover hidden patterns or relationships that may elude traditional statistical methods. By analyzing diverse sources of data, including clinical biomarkers, imaging studies, genetic information, lifestyle factors, and environmental exposures, ML algorithms can generate personalized risk profiles and identify individuals at heightened risk of experiencing a stroke.

One such method gaining traction is logistic regression, a statistical technique widely used in medical research for forecasting the likelihood of a binary outcome, relying on one or more predictor variables. Logistic regression offers several advantages, including simplicity, interpretability, and the ability to model nonlinear relationships between predictors and the outcome. By analyzing diverse sources of data, including clinical biomarkers, imaging studies, genetic information, lifestyle factors, and environmental exposures, logistic regression models can generate personalized risk profiles and identify the people at high end side of risk of experiencing a stroke. Emerging as a promising avenue is the application of machine learning techniques, with logistic regression standing out as a robust methodology. Logistic regression offers an intuitive framework for modeling the likelihood that an event will occur based on several predictor variables, making it well-suited for stroke risk prediction. Its interpretability and capability to accommodate nonlinear relationships between predictors and outcomes enhance its utility in identifying individuals susceptible to stroke. By leveraging diverse datasets encompassing clinical, genetic, and lifestyle factors, logistic regression-based models can generate personalized risk profiles, thus facilitating targeted preventive interventions. The integration of ML-based stroke risk prediction models with web-based applications represents a novel approach to delivering personalized preventive interventions and optimizing healthcare resources.

By leveraging the ubiquity and accessibility of web technologies, such as smart phones, tablets, and personal computers, these applications can empower individuals to take proactive steps to mitigate their risk of stroke and facilitate timely access to medical care. Furthermore, the use of web-based platforms enables seamless communication between patients, caregivers, and healthcare providers, facilitating shared decision-making and enhancing coordination of care. Detailing the design and execution of a logistic regression-based stroke risk prediction system coupled with a web application. Explicating the rationale underpinning this amalgamated approach, conducting a thorough review of relevant literature concerning stroke risk prediction and preventive interventions, and outline the structural framework and implementation procedures of the devised system. Additionally, the aim to elucidate the potential implications of the findings for future study, public health policy, and clinical practice endeavours in this domain. Through the fusion of logistic regression with web-based applications, initiative endeavours to pave the way for personalized stroke prevention and enhanced health outcomes.

Following is an overview of this paper's main contributions:

- Developed machine learning models that are capable of accurately estimating a person's risk of stroke by using diverse sets of predictors.
- Implemented a notification system to alert those classified as having a high risk of stroke, prompting them to seek medical evaluation.
- Providing personalized recommendations for medication, lifestyle modifications, and exercises tailored to each individual's risk profile.
- Enhancing early detection and preventive care methods to lower the occurrence and severity of stroke-related complications.

## II. LITERATURE SURVEY

### *A. Performance Analysis of Machine Learning Approaches in Stroke Prediction*

The importance of early stroke detection and the effects of strokes on individuals are covered in the study's opening section [1]. It emphasizes how crucial it is to take into account risk factors including diabetes, cholesterol, smoking, and alcohol intake when estimating the likelihood of a stroke. The potential of AI-driven solutions in stroke care specifically, in early detection, precise diagnosis, and decision support is also highlighted in this research. It presents the results of the performance analysis, showing the effectiveness of the proposed method. It compares the F1-score, recall, accuracy, and precision of various machine learning models and evaluates the impact of the near-miss under sampling technique on the models' functionality. It also includes the receiver operating characteristic (ROC) curve analysis, highlighting the (AUC) for each model. Overall, the proposed method outperformed existing techniques, achieving a significantly higher accuracy of approximately 98.83% at low cost, thus demonstrating its potential for accurate early stroke prediction.

### B. Management of Acute Ischemic Stroke

The most important thing when treating stroke patients is to identify the illness as soon as possible and direct them to facilities that have the necessary resources to treat them appropriately and on time. The data supporting pre-hospital and emergency stroke care are examined. This includes the application of emergency medical services protocols to identify stroke patients[2], the updating of patient eligibility criteria and treatment schedules for intravenous thrombolysis in acute ischemic stroke, and the use of advanced imaging techniques with automated interpretation to identify patients who have significant brain areas at risk but do not have completed infarcts, potentially benefiting from endovascular thrombectomy within extended periods from the onset of symptoms.

### C. Taxonomy and Survey of Including Previous Knowledge in Learning Systems for Informed Machine Learning

Informed Machine Learning, focusing on incorporating past knowledge into educational programs[3]. Proposed a structured taxonomy to categorize various approaches in this field, considering the knowledge's origin, form, and incorporation into the machine learning process. They emphasize the importance of incorporating prior knowledge to address the limitations of purely data-driven approaches, especially in scenarios with insufficient training data or constraints dictated by natural laws, regulatory guidelines, or security considerations. Highlights the use of knowledge graphs and neural networks have been combined in order to categorize images, showcasing how relationships among identified objects in images can be depicted as adjacency matrices in neural networks with gated graphs. This method enriches the capabilities of convolutional neural networks by integrating knowledge graphs that capture relationships among objects in real-world images.

### D. Review of the Big Data-Based Machine Learning Evaluation Criteria

Review starts by contextualizing machine learning emphasizing the importance of evaluating machine learning algorithms in this context [4]. It discusses the basic evaluation criteria commonly used in machine learning, such as accuracy, recall, F1-score, G-Mean index, ROC, and AUC. The paper also delves into other basic evaluation criteria, including the Kappa value and Gini coefficient, highlighting their significance in assessing the efficiency and goodness of machine learning algorithms. Furthermore, it concludes by emphasizing the need for further research to explore the pros and cons of different evaluation standards for machine learning and to propose specific use advantages for specific problems.

Evaluates big data-based machine learning standards [6], stressing the importance of evaluating machine learning algorithms and highlighting various evaluation methods used in this context. It offers insightful information about the significance of specific evaluation methods for various machine learning problems and emphasizes the need for more investigation in this field to investigate the pros and cons of different evaluation standards.

### E. Classification of Stroke using Machine Learning Algorithms

Discussed how patient case sheets can be used to classify stroke patients using machine learning (ML) algorithms [5] [7]. It provides a model that mines patient symptoms from case sheets using AI algorithms and text mining tools, then uses the collected data to train the system. In order to extract the common and distinct set of features to categorize strokes, the case sheets of 507 patients were gathered, mined, and processed using tagging, maximum entropy techniques, and a proposed stemmer. The processed data were then fed into a number of machine learning (ML) algorithms, such as boosting, bagging and boosting, support vector machines (SVM), and artificial neural networks (ANN), in order to achieve the classification. The introduction highlights the significance of health recording systems for tracking disease data, particularly for stroke, and the need to classify strokes accurately. The document categorizes strokes into ischemic stroke (IS), hemorrhagic stroke (HE), and transient ischemic attack (TIA), outlining their characteristics and prevalence. It also reviews related works on stroke prediction using ML algorithms, emphasizing the importance of accurate classification and the challenges associated with stroke treatment and prediction.

### F. DRFS: Machine Learning Algorithms to Detect Stroke Risk Factors from Social Media

Employs diverse datasets and algorithms such as NN, SVM, LASSO, ElasticNet, Support Vector Machine, Random Forest, and Logistic Regression, K-nearest neighbours, and Naïve Bayes for stroke prediction. Additionally, bioelectrical signals, deep neural network, and ensemble methods are utilized for stroke prediction. Confusion matrices, accuracy, precision, recall, F1-score, and ROC curves are among the metrics used to compare the performance of various algorithms during the training and testing phases. The results show that the Stacking of ensemble methods performs exceptionally well in stroke prediction, highlighting the potential of machine learning to improve prediction. The conclusion emphasizes the significance of early stroke prediction and the machine learning models reduce the impact of stroke occurrences. The study plans to expand its scope by incorporating image data such as ECG, Brain CT scans, and MRI in the future, suggesting the potential for further advancements in stroke prediction using machine learning techniques. The paper provides valuable insights into the application of machine learning algorithms and convolutional neural network models in stroke risk prediction, underscoring the potential for improved stroke prognosis and treatment outcomes.

*G. Machine Learning Techniques for Prognosis and Prediction of Functional Recovery in Post-Stroke Rehabilitation*

The systematic evaluation conducted by Campagnini et. al. [11] delves into the realm of post-stroke rehabilitation, focusing on machine learning techniques to forecast prognosis and functional recovery. The study investigates a wide array of research articles to discern trends, challenges, and advancements in this domain. The review underscores the increasing utilization of machine learning techniques in post-stroke rehabilitation, emphasizing their potential to enhance personalized treatment strategies and improve patient outcomes. Numerous ML algorithms, including random forests and support vector machines, among others, and artificial neural networks, have been explored for their efficacy in predicting functional recovery and prognosis. Challenges identified in the literature include the need for larger, more diverse datasets, as well as the necessity of standardizing evaluation metrics and methodologies to ensure comparability across studies. Additionally, the review emphasizes the significance of interpretability and transparency in machine learning models, particularly in clinical settings where decisions directly impact patient care.

*H. Enhancing Dynamic Stroke Risk Prediction in Individuals with and without Atrial Fibrillation Who Are Not on Anticoagulant Therapy*

The research aims to address the limitations of conventional risk assessment tools by leveraging machine learning techniques, which have demonstrated potential in a number of medical applications [12]. By comparing the performance of common clinical risk scores with machine learning algorithms, research aims to identify more accurate and reliable methods for dynamic stroke risk prediction. Key aspects of the study likely include the selection and evaluation of different neural networks, random forests, and support vector machines are examples of machine learning algorithms, alongside established clinical risk scores like CHA2DS2-VASc and HAS-BLED. Specificity, sensitivity and (AUC) are the metrics of evaluation may be utilized to the predictive performance of each method. The article likely provides the potential of machine learning to enhance stroke risk prediction in clinical practice, particularly in non-anticoagulated patients without and with AF. Additionally, it may highlight the importance of incorporating advanced computational techniques into existing risk assessment frameworks.

*I. Predicting Atrial Fibrillation After an Ischemic Stroke using Machine Learning*

By leveraging data from various patient demographics, clinical characteristics, and medical history, the authors aim to develop predictive models capable of early detection and intervention Key components of the research may involve the selection and evaluation of different machine learning algorithms, such as decision trees, logistic regression, support vector machines to determine which approach yields the most accurate predictions [13]. Insights gleaned from this study could have significant implications for clinical practice by enabling healthcare providers to proactively identify patients at heightened risk of developing AF post-ischemic stroke. Early detection of AF could facilitate timely interventions, potentially reducing the risk of recurrent strokes and improving patient outcomes. Furthermore, the study may underscore the value of incorporating machine learning methodologies into cardiovascular risk assessment protocols to enhance predictive accuracy and inform personalized patient care strategies.

*J. A Prospective Observational Study of A Machine Learning-Based Pre-Hospital Stroke Diagnostic System*

Key components of the research likely include the selection and training of ML algorithms, such as support vector machines, random forests and neural networks, using data collected from pre-hospital settings. Evaluation metrics like sensitivity, specificity, and area under the curve (AUC) are used to know the algorithm's performance in stroke diagnosis. Insights from this study could have significant implications for stroke care by enabling timely intervention and potentially reducing long-term disability and mortality associated with strokes. Additionally, the development of a pre-hospital diagnostic algorithm may contribute to more efficient resource allocation and improved triage strategies, optimizing the delivery of care for stroke patients. Overall, this work demonstrates the promise of machine learning, to enhance diagnostic capabilities and improve patient outcomes in pre-hospital settings.

*K. Stroke Probability Prediction and Data Visualization using Various Machine Learning Models*

The study likely involves the application of several machine learning methods to predict the likelihood of stroke occurrence based on a combination of relevant features such as demographic data, medical history, and lifestyle factors. Multiple machine learning models are likely trained and compared to identify the most accurate and reliable approach for stroke probability prediction. Furthermore, the paper likely discusses the implementation of data visualization techniques for presenting the predictive results in a comprehensible and informative manner. Visualization methods such as heat maps, scatter plots, and decision boundaries may be employed to provide insights into the connections between various factors and how they affect the likelihood of a stroke. The research presented in this paper have significance in the healthcare as it aims to provide clinicians and healthcare professionals with valuable tools for early stroke risk assessment and visualization of predictive insights. By leveraging machine learning and data visualization techniques, the study contributes to improving stroke prevention strategies and facilitating informed decision-making in clinical practice.

## III. Methodology and Architecture

The architecture for stroke risk prediction and proactive health management encompasses a modular design that facilitates seamless data flow and interaction between various components. It consists of three main modules: Data Collection and Pre-processing, Machine Learning Model Development, and Web Application Integration.

*A. Data Collection and Pre-processing*

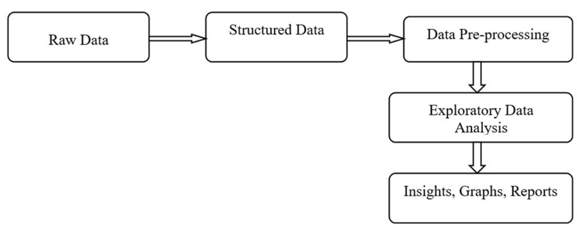



Figure 1. Data Preparation

This module is in charge of compiling pertinent medical data from various sources and getting it ready for analysis. Among the main sources are laboratory test results, Electronic Health Records (EHRs), reports on medical imaging, and lifestyle information gathered via wearable technology or user input. Vital signs, biomarkers, medical history, demographic data, and lifestyle elements like exercise and food may all be included in the data collection.

Data quality and consistency are ensured by pre-processing procedures before being fed into machine learning models. This entails actions to extract important features, encoding categorical variables for model compatibility, and data cleaning to manage missing or incorrect values. Furthermore, methods like outlier detection and dimensionality reduction may be employed to optimize data quality and model performance.

*B. Machine Learning Model Development*

This module predicts a person's risk of stroke by training and assessing machine learning algorithms with pre-processed healthcare data. To find the best strategy, a number of supervised learning techniques are investigated, such as logistic regression, neural networks, random forests, decision trees, support vector machines (SVM).

The data is separated into training, validation, and test sets in order to train and evaluate the models. Cross-validation techniques, like k-fold cross-validation, are employed to assess the model's performance and generalizability. In order to optimize performance parameters such as area under the receiver operating characteristic curve (AUC-ROC), accuracy, precision, and recall, hyper-parameter tweaking and model selection are carried out. Once the models are trained and validated, they are ready for deployment within the web application for real-time risk assessment and personalized health recommendations.

*C. Web Application Integration*

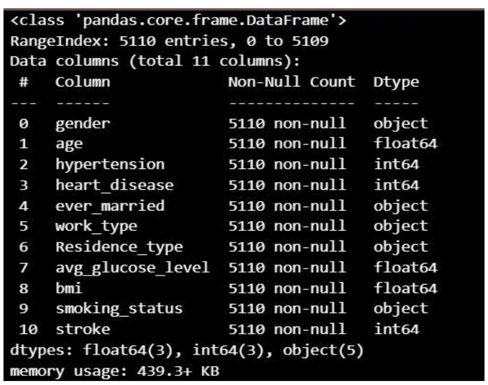
The web application allows users to interact with the system, enter personal information, evaluate risk assessments, and obtain health advice. It has a user-friendly interface and a responsive design to enable compatibility across multiple devices and platforms. The online application works with trained machine learning models to deliver real-time risk ratings based on user profiles. After receiving user input, the application pre-processes the data before passing it to the deployed models for prediction. The anticipated risk levels are then displayed to the user, along with tailored advice for medicine, exercise, lifestyle changes, and preventive actions. The application also includes capabilities like arranging doctor appointments, discovering nearby hospitals or healthcare institutions, and tracking health metrics over time. It may also include elements that encourage user participation and adherence, such as reminders, progress tracking, and stroke prevention and management education. Overall, the architecture makes it easier to integrate data collecting, machine learning model development, and web application deployment, allowing users to control their health and prevent strokes.

## IV. Implementation

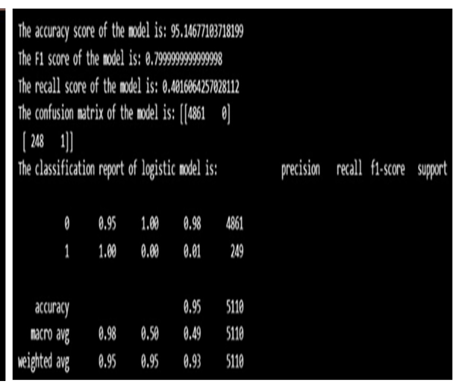
Predicting strokes with machine learning's primary goal is to use the random forest concept with the aid of binary trees and other methods such as the K-Nearest Neighbor (KNN) Algorithm, Logistic Regression, and then hyper-parameters have been employed to fine-tune this technique. This approach has processed the analysis of stroke and made it easy to forecast. It is now possible to simply categorize and implement machine learning algorithms with the goal of increasing performance benchmarks.

### *A. Data Preprocessing*

Database includes a list of data and string values that have undergone Exploratory Data Analysis (EDA) processing; the string values include integer encoding. The list of null values was then retrieved, and the integer values were converted into binary representations. Some of the values in the attributes were missed, resulting in their representation as N/A, but we changed them to zero in order to prevent the null value exception. Other ML techniques have been employed to analyze the training of the dataset once all null value operations and data extraction have been completed.



```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5110 entries, 0 to 5109
Data columns (total 11 columns):
 #   Column             Non-Null Count  Dtype
---  ------             --------------  -----
 0   gender             5110 non-null   object
 1   age                5110 non-null   float64
 2   hypertension       5110 non-null   int64
 3   heart_disease      5110 non-null   int64
 4   ever_married       5110 non-null   object
 5   work_type          5110 non-null   object
 6   Residence_type     5110 non-null   object
 7   avg_glucose_level  5110 non-null   float64
 8   bmi                5110 non-null   float64
 9   smoking_status     5110 non-null   object
 10  stroke             5110 non-null   int64
dtypes: float64(3), int64(3), object(5)
memory usage: 439.3+ KB
```

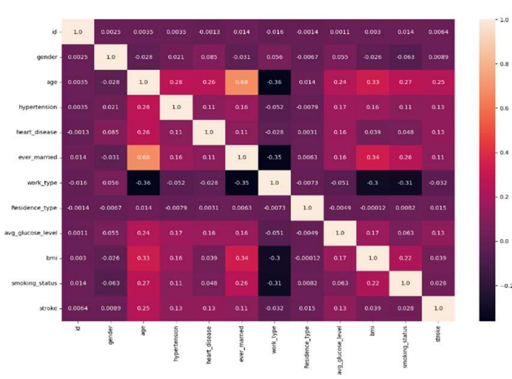


```
The accuracy score of the model is: 95.14677103718199
The F1 score of the model is: 0.7999999999999998
The recall score of the model is: 0.4016064257028112
The confusion matrix of the model is: [[4861    0]
 [ 248    1]]
The classification report of logistic model is:          precision    recall  f1-score   support

           0       0.95      1.00      0.98      4861
           1       1.00      0.00      0.01       249

    accuracy                           0.95      5110
   macro avg       0.98      0.50      0.49      5110
weighted avg       0.95      0.95      0.93      5110
```

Figure 2. Data Preprocessing Example

Figure 3. Measures of the ML Model

### *B. Logistic Regression Algorithm*



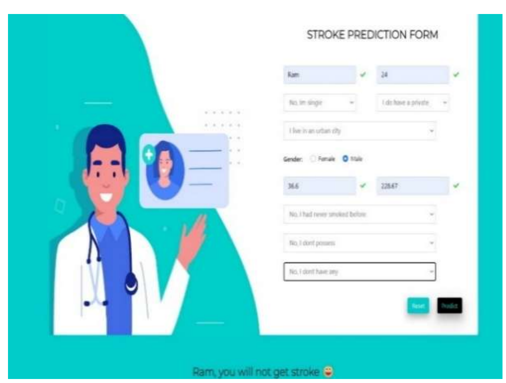




Figure 4. Correlation matrix between features.

Figure 5. StrokeRrisk Diagnosis-I

A machine learning model called logistic regression is used to classify binary data. It is mostly used to group problems, identify different sections of the image, and help classify the components when discrete values need to be predicted. The logistic regression's response variable is of an unmitigated kind. It helps determine the likelihood of a particular event occurring. While binary classification refers to situations in which our output predictions can only take one of the two possible values, such as 0 or 1, or else true or false, there are some real-world applications for logistic regression, such as determining whether an email is spam or not. Logistic regression is utilized when our output prediction can take either of the values meaning either this value or that value. It can also be used to determine if the person has an illness or not, or to determine whether the tumour is malignant or not.

## V. Results

The intended research seeks to formulate a web application for prediction, leveraging ML techniques. Users will input key attributes such as gender, age, history of heart disease, smoking and drinking habits, body mass index (BMI), and hypertension status. These attributes serve as input features for a trained predictive model, which will determine the likelihood of the individual experiencing a stroke.

Upon analysis, if the model predicts an elevated risk of stroke, the system will trigger an automatic notification to the user, advising them to schedule a doctor's appointment promptly. Additionally, personalized recommendations will be provided, including tailored exercise routines to mitigate risk factors, guidance on nearby hospitals equipped to handle stroke cases, and recommendations for preventive medications. The goal is to empower individuals with proactive measures to reduce their risk of stroke and facilitate timely medical intervention when necessary.

This study closes the divide between machine learning and healthcare by providing a user-friendly interface for stroke risk assessment. By integrating predictive analytics with actionable insights, the web application offers a valuable tool for both individuals and healthcare providers. Through this proactive approach, the system not only facilitates early detection and intervention but also promotes healthier lifestyle choices, ultimately contributing to improved public health outcomes in the prevention and management of stroke.

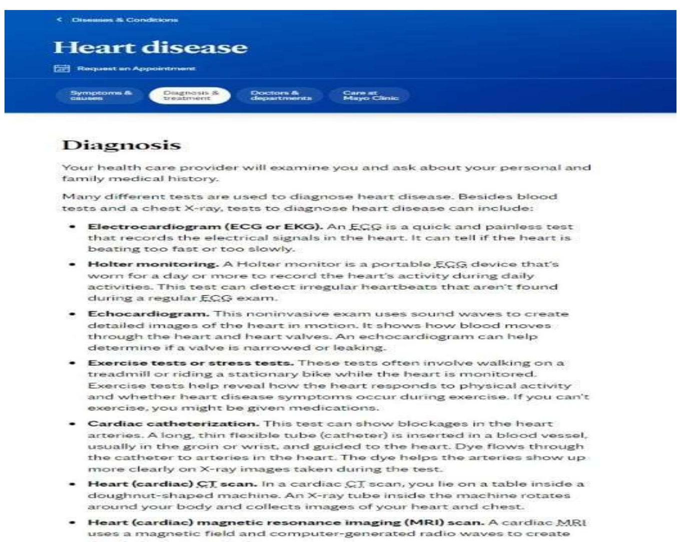



Figure 6. Suggested Recommendations

## VI. Conclusions

In final result, there's a lot of scope for enhancing early diagnosis and preventative care approaches with the creation of a machine learning-based stroke risk prediction system. Through the utilization of sophisticated algorithms and the integration of varied information, we are able to precisely evaluate a person's risk of suffering a stroke and offer prompt measures to reduce that risk. With the use of the suggested system's user-friendly interface, people can quickly find out their stroke risk status. The technology immediately alerts the user in the event of an elevated risk and offers practical advice, such as making an appointment with a doctor, prescribing

medication, pointing out the closest hospital, and recommending certain activities. In the end, this proactive strategy lowers the incidence and severity of health problems by enabling people to take charge of their health and by facilitating prompt medical intervention.
Future enhancements for the stroke risk prediction system include integrating wearable devices for real-time data, analyzing longitudinal data to track risk trajectories, integrating multimodal data sources for enriched models, continuous model improvement, enhancing decision support for healthcare providers, expanding to predict other health conditions, and ensuring global accessibility. These advancements aim to ultimately reducing the burden of stroke.

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