Cardiac Stroke Risk Stratification using Classification Model

Taesun Yoo

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Springboard

Cardiac Stroke Statistics: US in 2017

1 in 20 deaths

Accounts from cardiac stroke

Rank #5

Among all causes of death in US, killing 133K people a year

795K people

Experience a new or recurrent stroke

$52 Billion

Estimated indirect and direct costs for stroke

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Problem Statement

Why should you care?

- Stroke is a preventive condition (i.e., lifestyle and dietary)
- ↑ in projected stroke prevalence US
- ↑ in cost for stroke treatment ($)

Stakeholders:

- Chain of hospitals: cardiac care unit managers and clinicians

Goal:

- Predict patients with high risks of developing a stroke

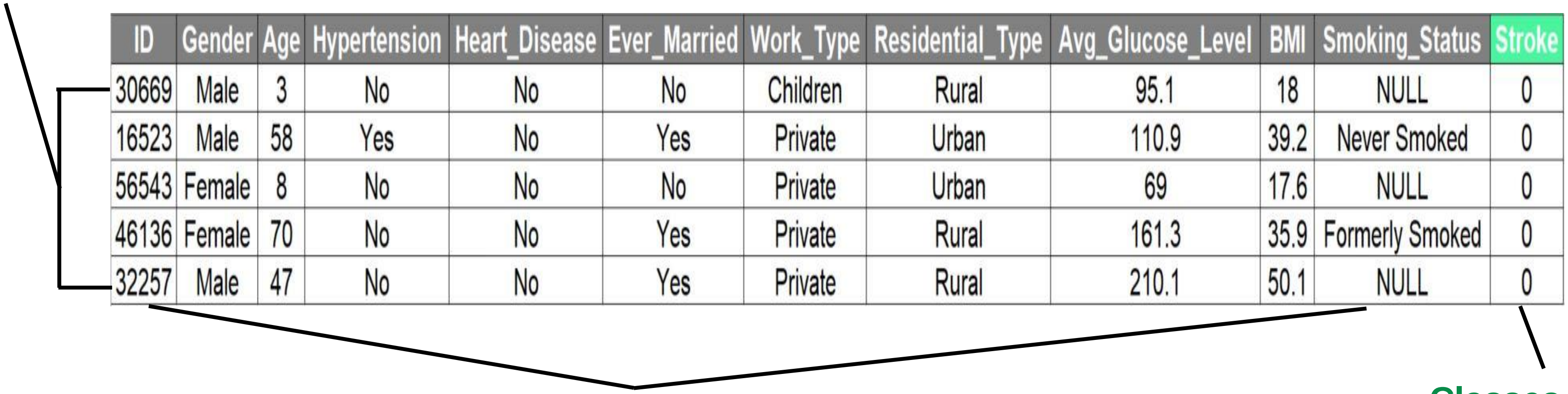
Objective:

- Help physicians to take proactive cardiac health monitoring
- Target prevention on patients with high risk of stroke

Dataset Overview

Dataset contains **11** input features for predicting an “**stroke**” label:

- 8 categorical & 3 numerical features
- Lifestyle and health demographic indicators
- Sample size = 43,000 rows



Observations (rows)

ID	Gender	Age	Hypertension	Heart_Disease	Ever_Married	Work_Type	Residential_Type	Avg_Glucose_Level	BMI	Smoking_Status	Stroke
30669	Male	3	No	No	No	Children	Rural	95.1	18	NULL	0
16523	Male	58	Yes	No	Yes	Private	Urban	110.9	39.2	Never Smoked	0
56543	Female	8	No	No	No	Private	Urban	69	17.6	NULL	0
46136	Female	70	No	No	Yes	Private	Rural	161.3	35.9	Formerly Smoked	0
32257	Male	47	No	No	Yes	Private	Rural	210.1	50.1	NULL	0

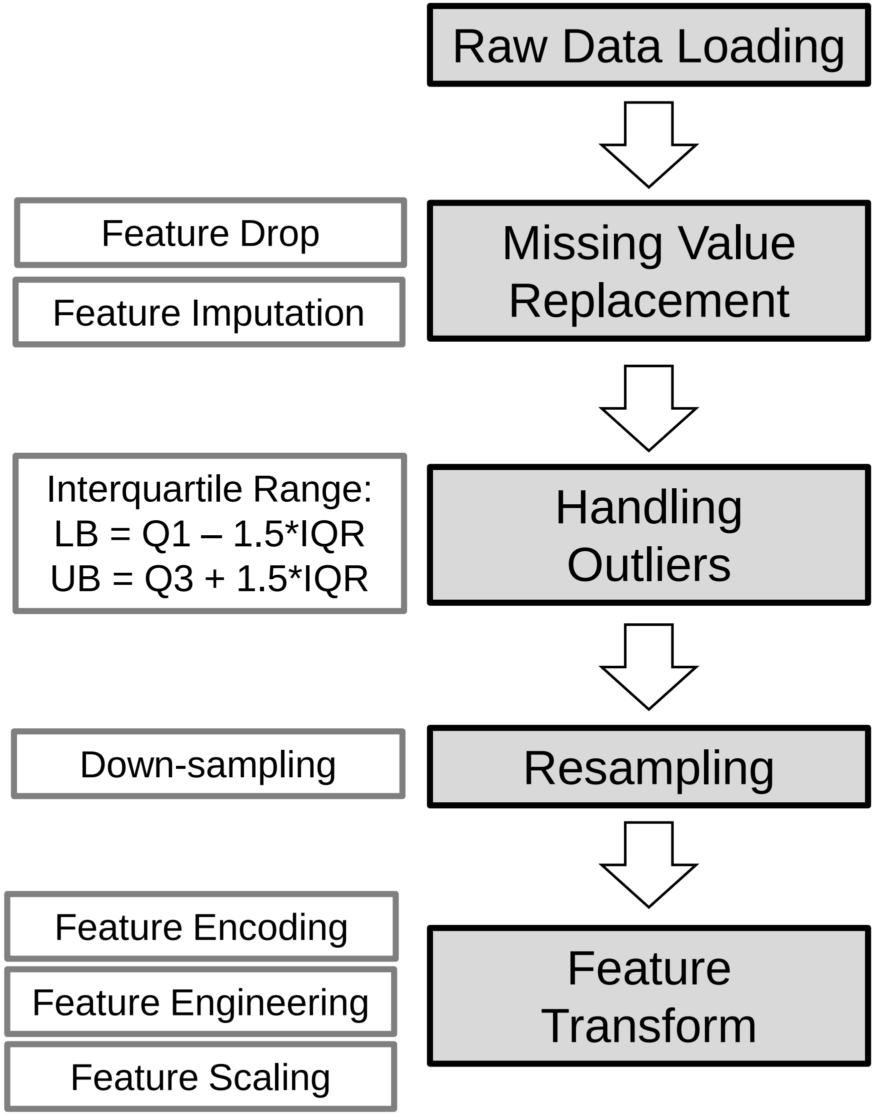
Features (attributes)

Classes (label)

Challenges:

- Class imbalance (98% healthy vs. 2% stroke)
- Outliers & duplicates
- Missing values

Data Wrangling

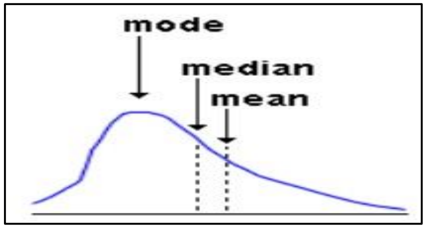


Raw Data Loading

Feature Drop

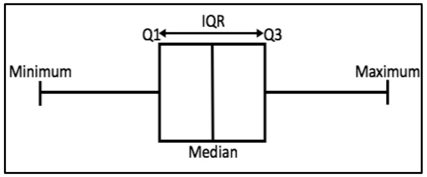
Feature Imputation

Missing Value Replacement



Interquartile Range:
LB = Q1 – 1.5*IQR
UB = Q3 + 1.5*IQR

Handling Outliers



Down-sampling

Resampling

Non-stroke (50%)	Stroke (50%)

Feature Encoding

Feature Engineering

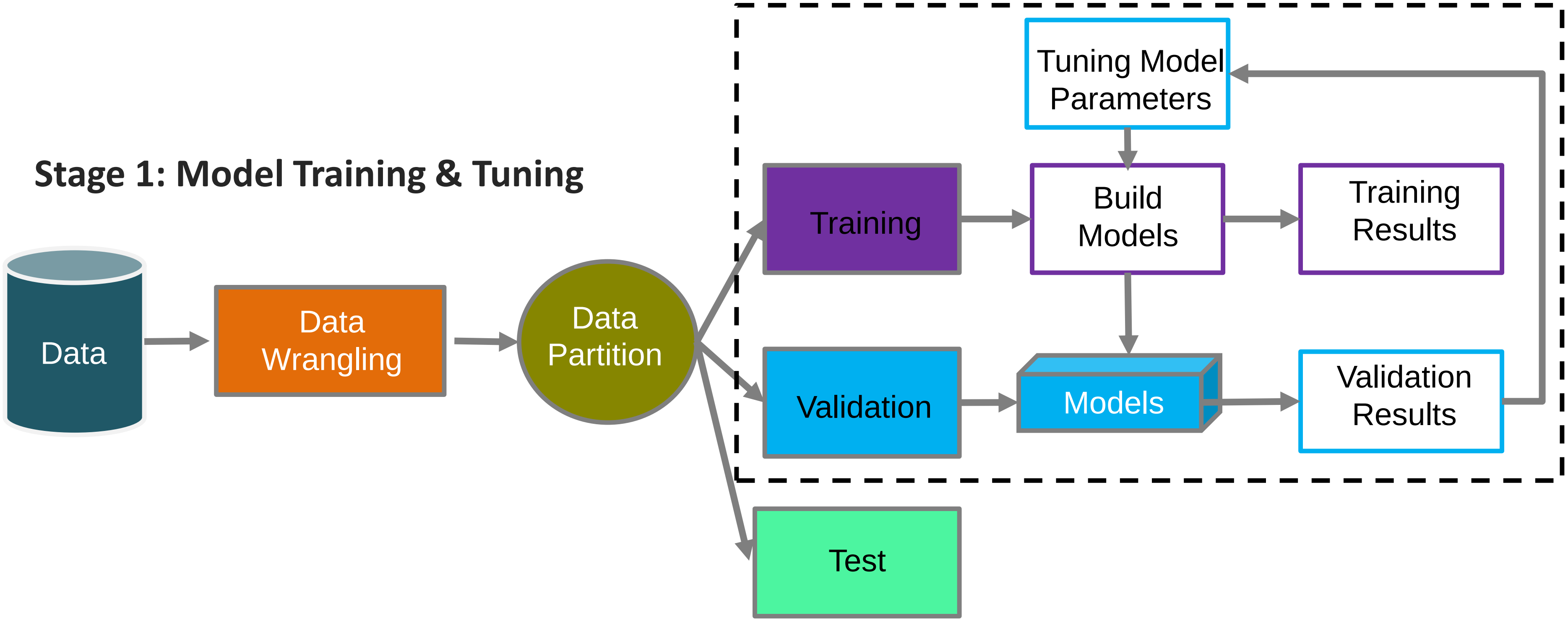
Feature Scaling

Feature Transform

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Classification Model Workflows

Stage 1: Model Training & Tuning



Data

Data Wrangling

Data Partition

Training

Validation

Test

Tuning Model Parameters

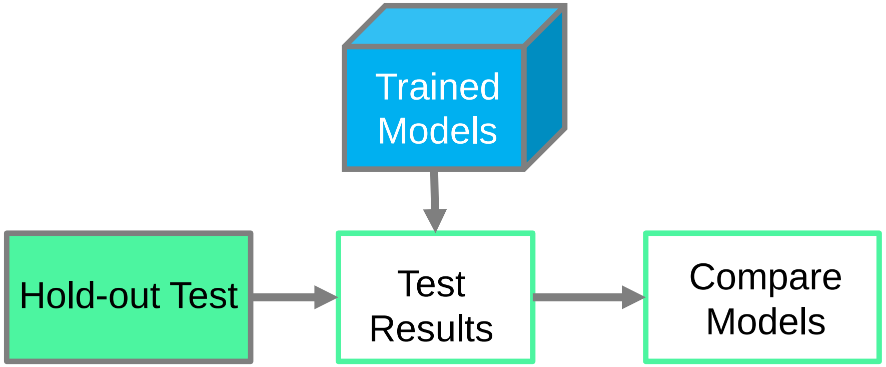
Build Models

Training Results

Models

Validation Results

Stage 2: Model Performance Estimate



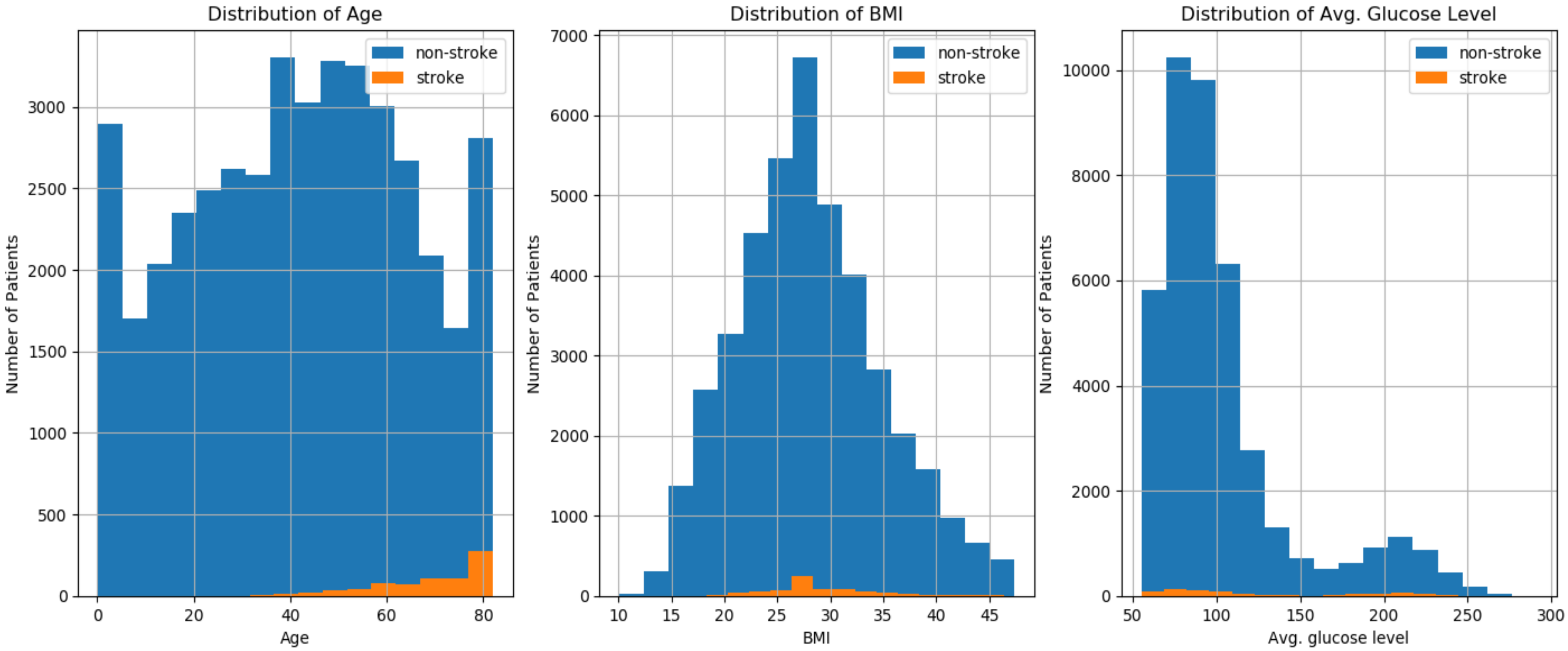
Trained Models

Hold-out Test

Test Results

Compare Models

Distributions: Healthy vs. Stroke Population

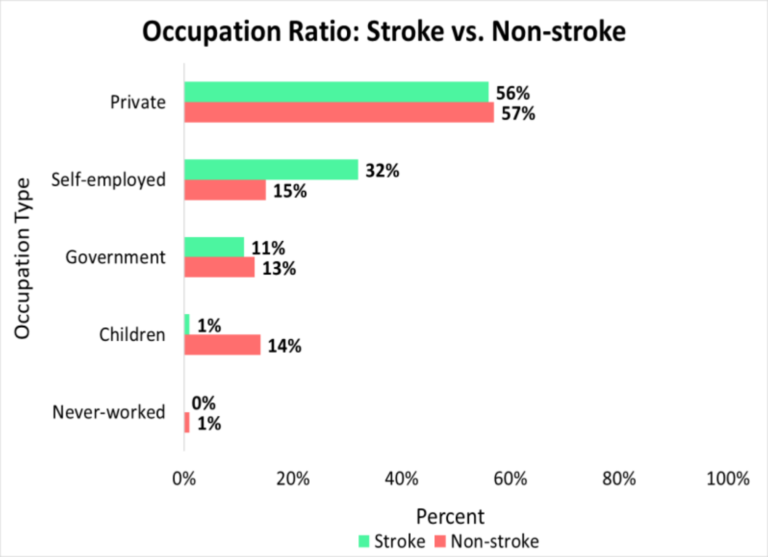


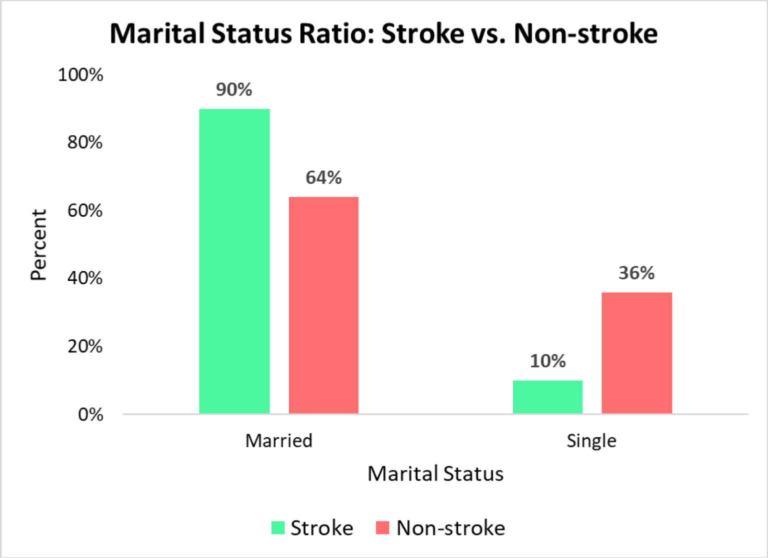
Age: majority of senior stroke patients (skewed to left)

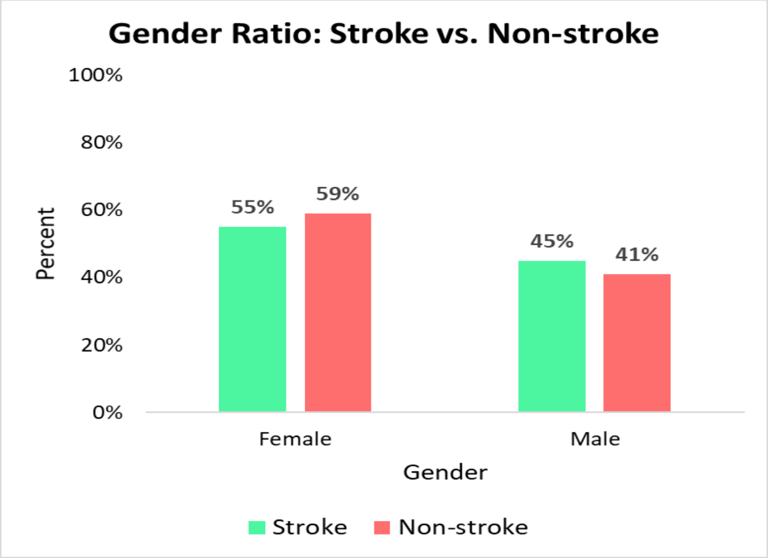
BMI: normal distribution (centralized from 25 to 30)

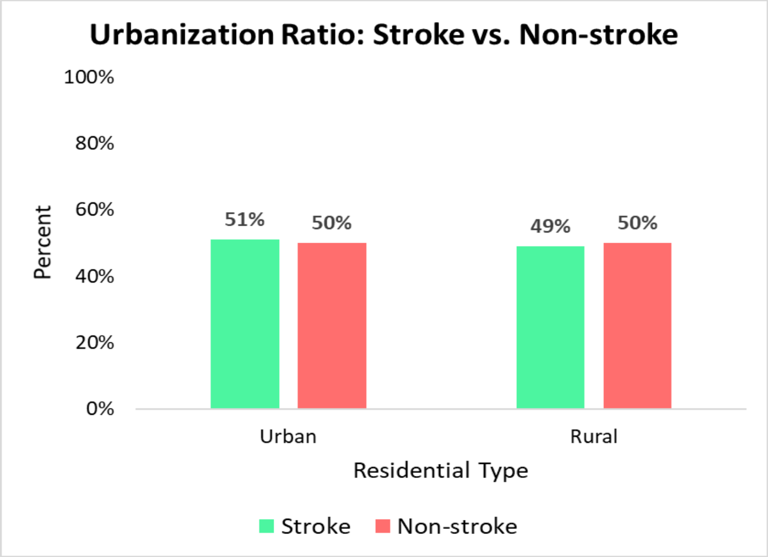
Avg. glucose level: non-normal distribution (bi-modal peaks)

Lifestyle Factors: Healthy vs. Stroke Population


Occupation Ratio: Stroke vs. Non-stroke


Marital Status Ratio: Stroke vs. Non-stroke


Gender Ratio: Stroke vs. Non-stroke


Urbanization Ratio: Stroke vs. Non-stroke

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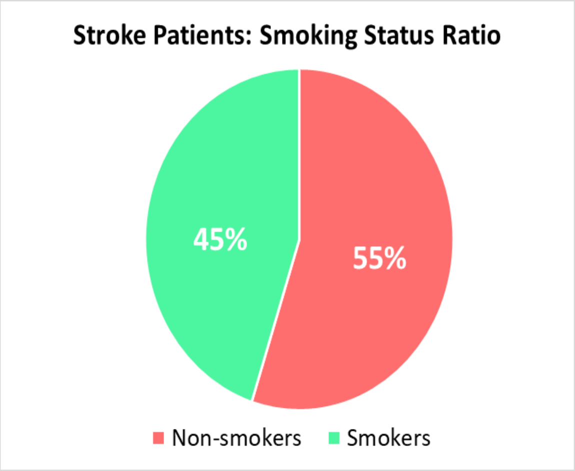
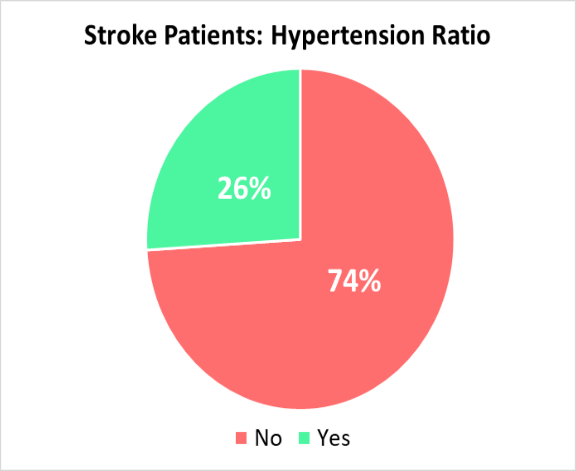
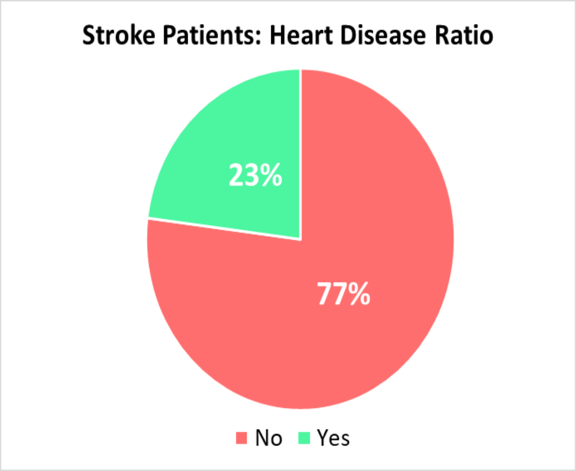
Health Indicators: Healthy vs. Stroke Population

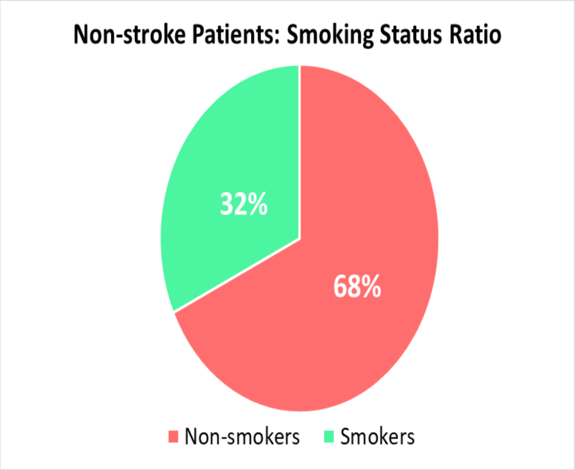
Stroke

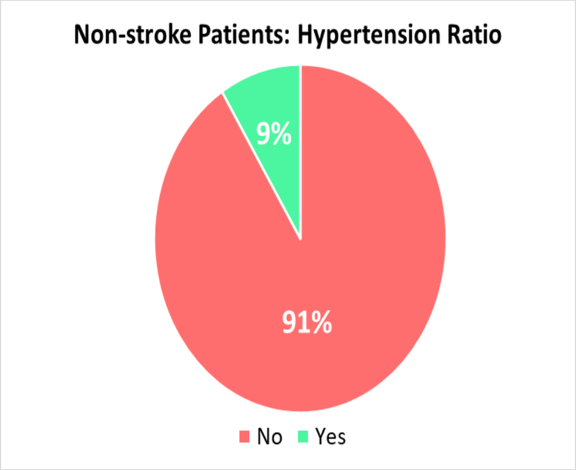


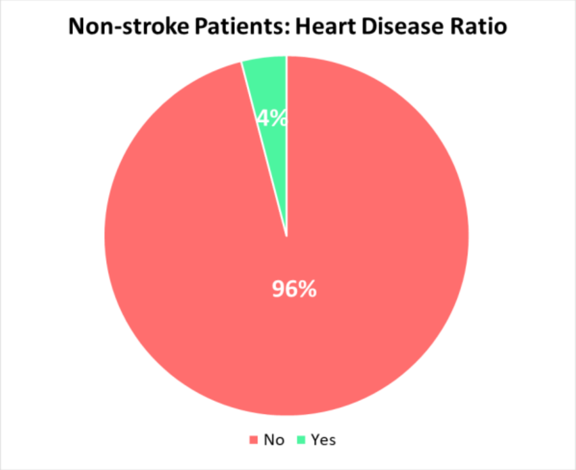




Non-stroke







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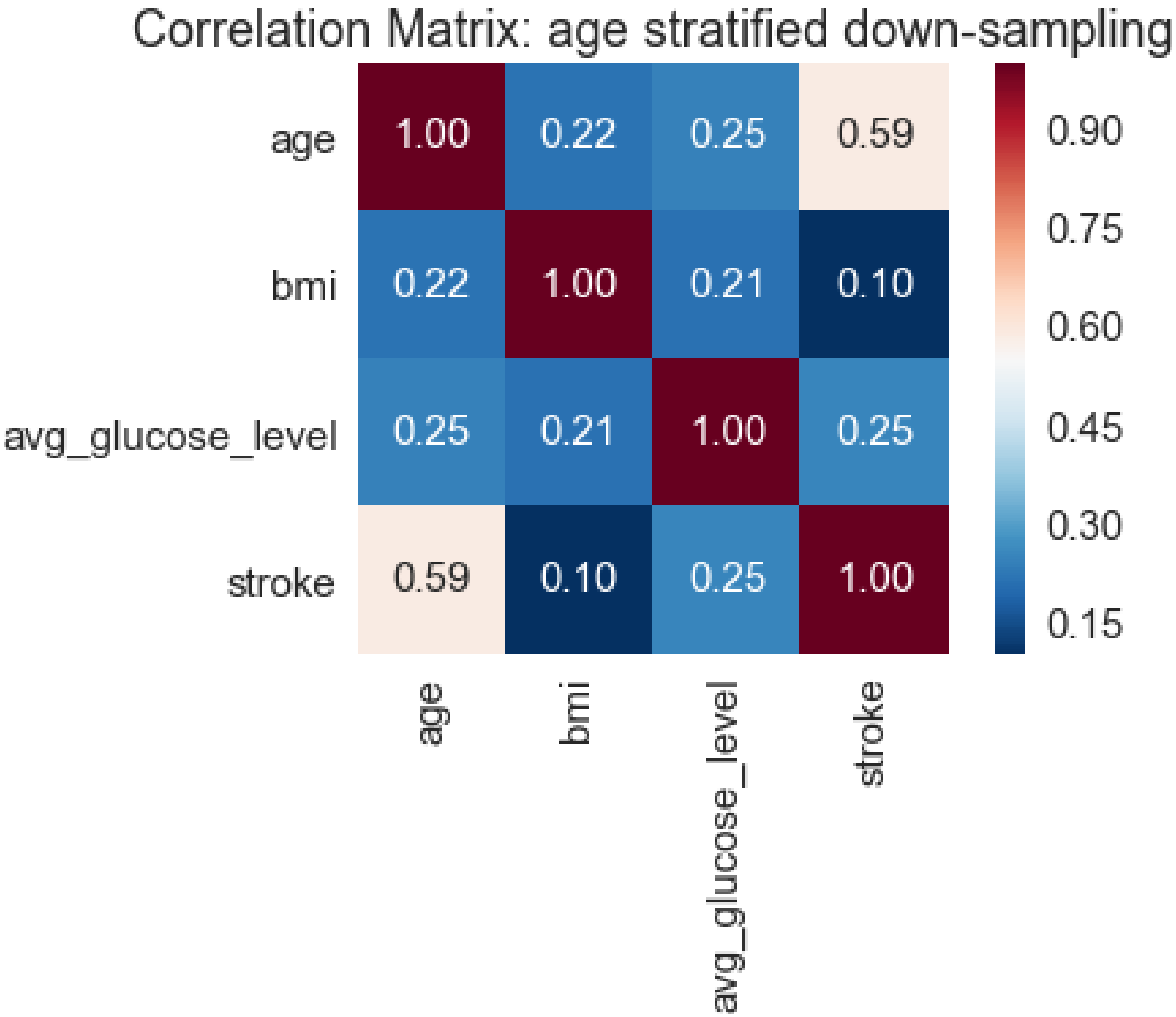
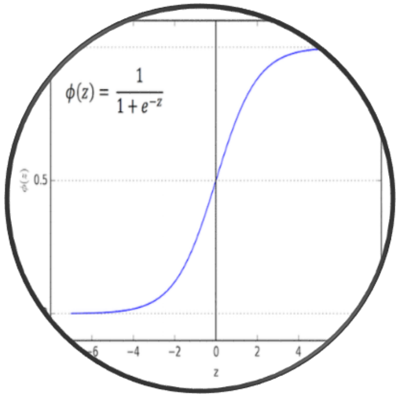
Correlation Matrix



Correlation Matrix: age stratified down-sampling

	age	bmi	avg_glucose_level	stroke
age	1.00	0.22	0.25	0.59
bmi	0.22	1.00	0.21	0.10
avg_glucose_level	0.25	0.21	1.00	0.25
stroke	0.59	0.10	0.25	1.00

Model Selections

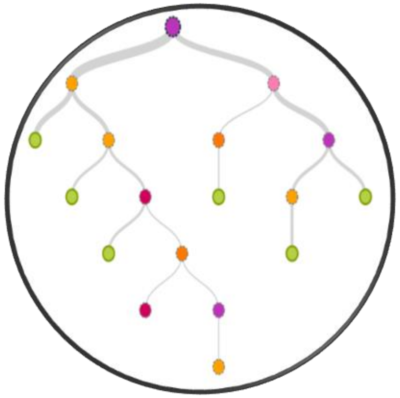


Logistic Regression

Sigmoid logit function:
log(p/(1-p))

Transforms:
Linear reg. → Logistic reg.
into a range (0, 1)

Works well on linearly separable classes.

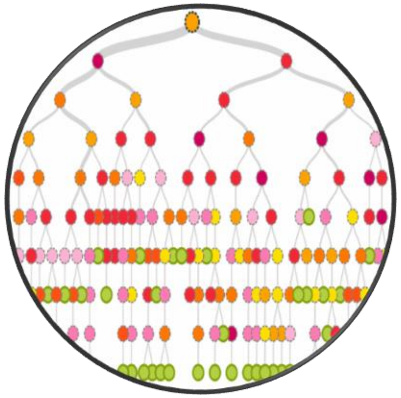


Decision Tree

Split data on features.

Repetitive splitting procedure.

Continue splitting until each node left with same class label.

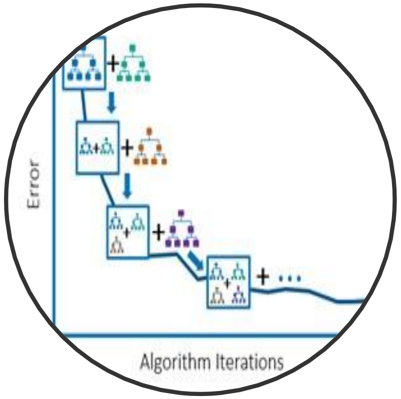


Random Forest

Ensemble learning.

Creates many decision trees.

Average performance of trees.



Gradient Boost

Sequential training.

Learn from residual errors.

Step-wise forward

$$\boxed{\text{Label} = \text{mode}\ \{c_{lr}(x),\ c_{dt}(x),\ c_{rf}(x),\ c_{xgb}(x)\}}$$

Majority Vote

Meta-classifier

Combination of four models

Improves accuracy of model performances by majority vote

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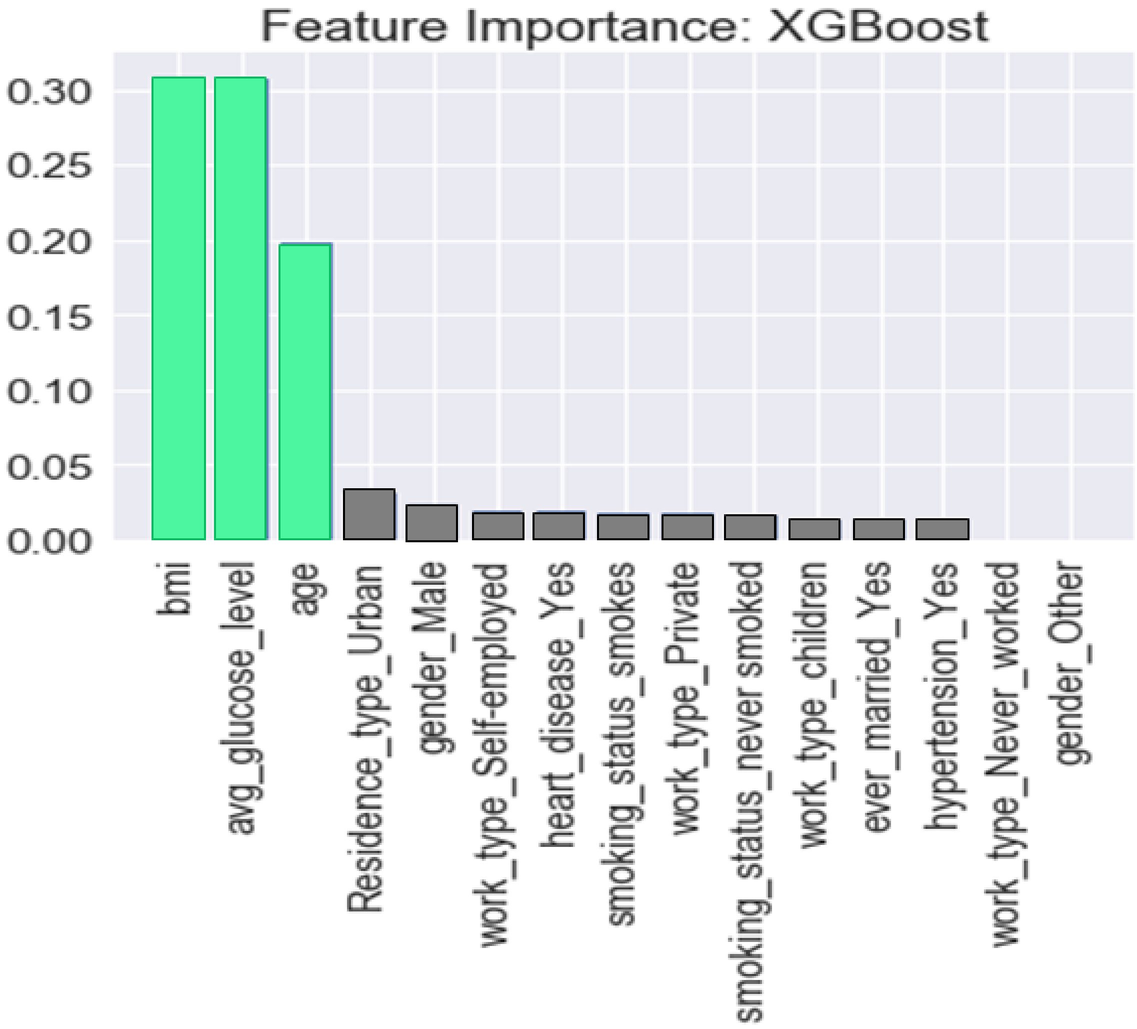
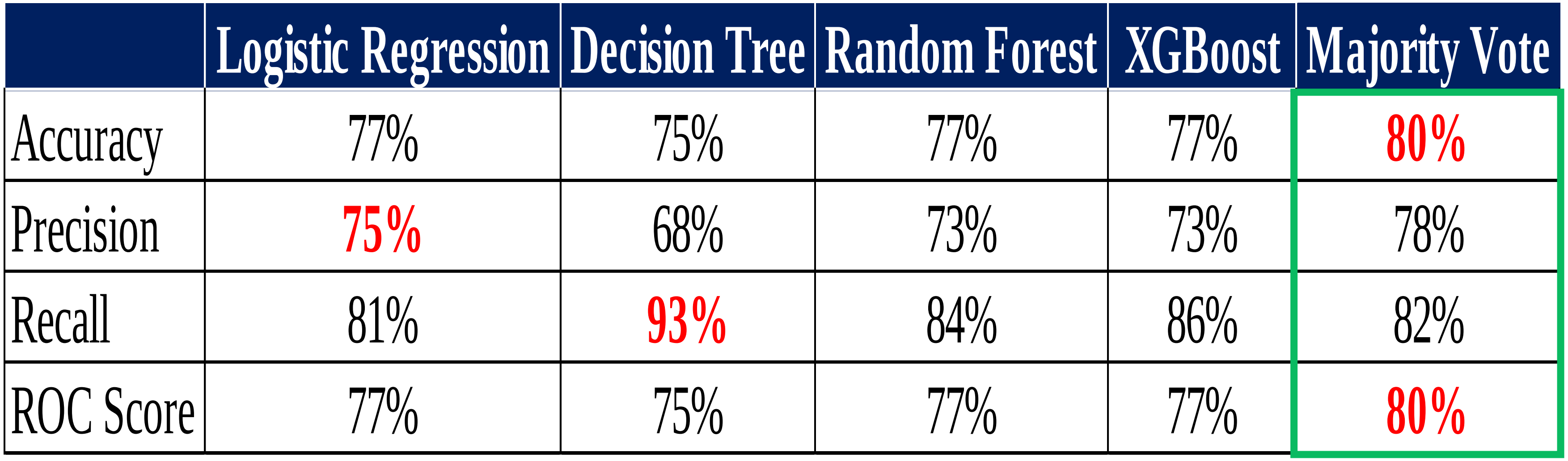
Feature Selections



Model Comparison



	Logistic Regression	Decision Tree	Random Forest	XGBoost	Majority Vote
Accuracy	77%	75%	77%	77%	**80%**
Precision	**75%**	68%	73%	73%	78%
Recall	81%	**93%**	84%	86%	82%
ROC Score	77%	75%	77%	77%	**80%**

Overall, in terms of evaluation metrics:

- Best performing model was “Majority Vote classifier”

Confusion Matrix

MajorityVote Classifier

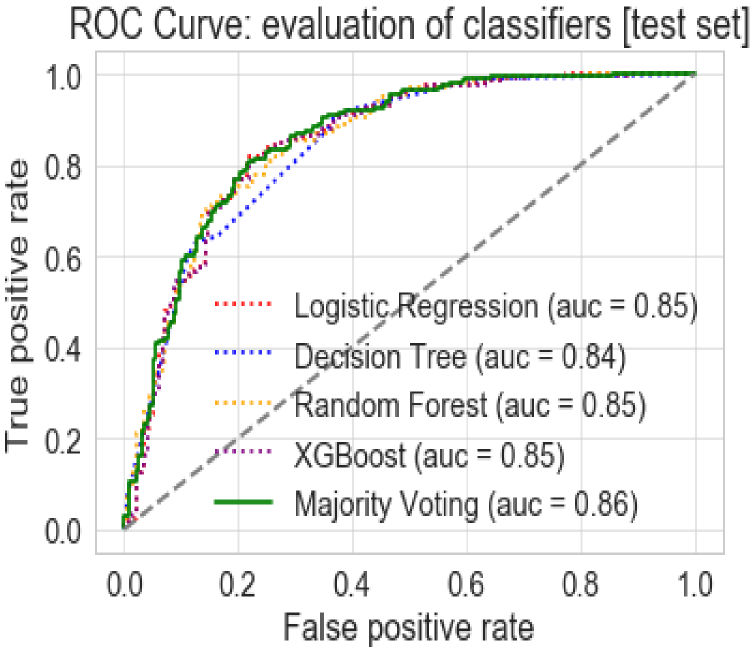
	Predicted Class	
Actual Class	**Stroke**	**Non-stroke**
Stroke	**41%**	**9%**
Non-stroke	**11%**	**39%**

Outcome Interpretation:

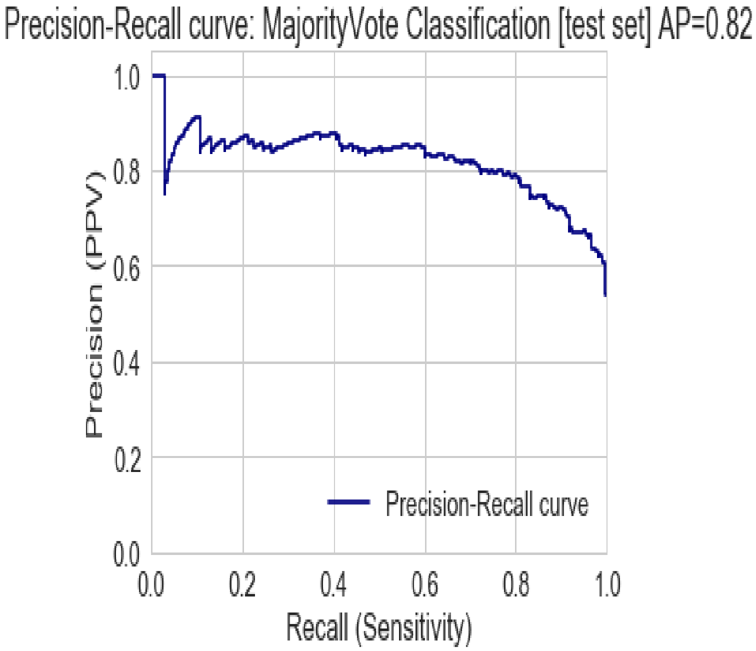
- 80% of correct predictions
- 20% of mis-classification errors

Balance between ML model and human intervention is required especially on **9% error** (*Type II error*).

ROC and Precision-Recall Curves



ROC Curve



Precision-Recall Curve

Summary: Stroke Classification

Goal

Predict cases at high risks of developing a stroke by classification model

Results

- Model was able to predict whether or not patients were at risk of stroke
- 80% of accurate predictions were made on test set of stroke data

Risks & Mitigation

Risks:
Model incorrectly classified with 9% error as likely patients are healthy but in fact had strokes

Mitigation:
Review identified cases with a group of clinicians before decision making

Next Steps

- Collection of meaningful features
- Model improvement: algorithms, resampling and designs

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Limitations & Future Work

Limitation:

- Absence of useful features/attributes
- Weak feature interaction (i.e., smoking, hypertension)

Future Work:

- Collection of features (i.e., genetic pre-disposition, physical activity, etc.)
- Model improvement: combine multiple classifiers
  - Stacking
  - Other ensemble
- Resampling strategies:
  - SMOTE
  - Oversampling (i.e., minority class: stroke cases)
- Age stratified classifiers:
  - Younger patients cohort (age < 30)
  - Senior patients cohort (age > 50)

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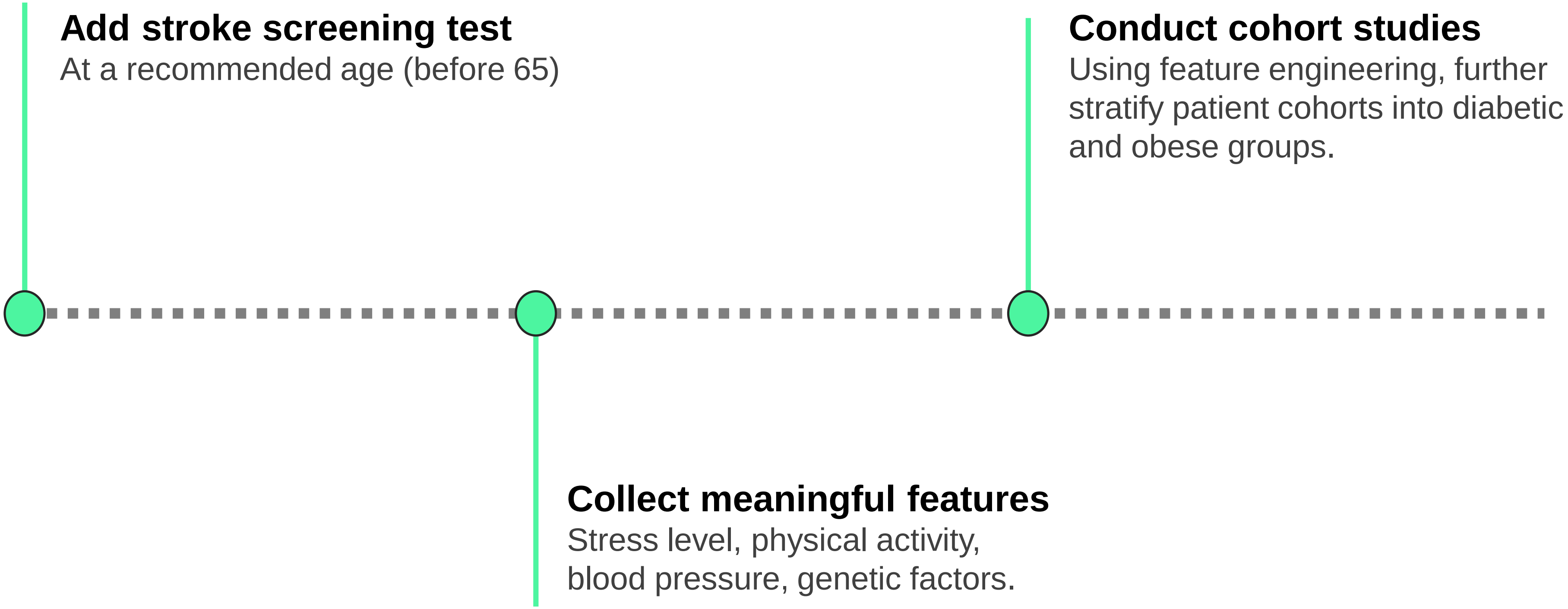
Recommendations



Add stroke screening test
At a recommended age (before 65)

Collect meaningful features
Stress level, physical activity, blood pressure, genetic factors.

Conduct cohort studies
Using feature engineering, further stratify patient cohorts into diabetic and obese groups.

Thank You!

Questions?

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