Stroke Severity

Understanding Stroke Patterns at Piedmont Athens Regional

PRESENTED BY

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Background

Definition

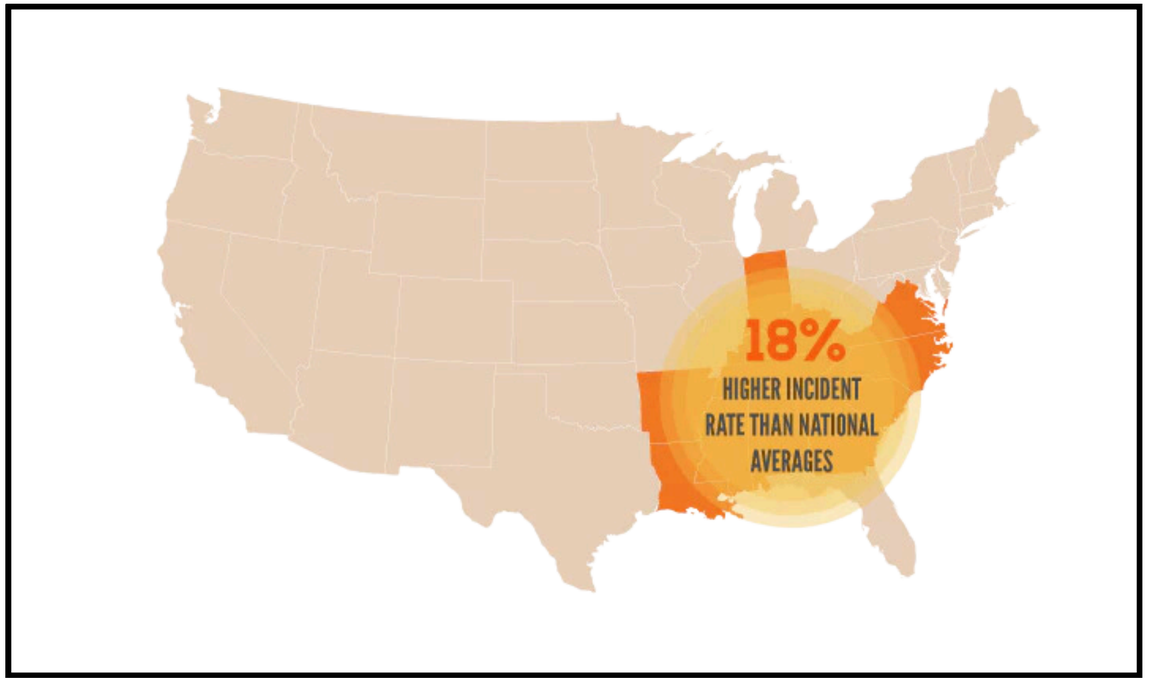
- Brain damage caused by:
  - **Ischemic: Blood flow blockage**
    - Most common
  - Hemorrhagic: Brain bleed

Effects

- Impacts movement, speech, memory
- High blood pressure, obesity, smoking, age

Significance

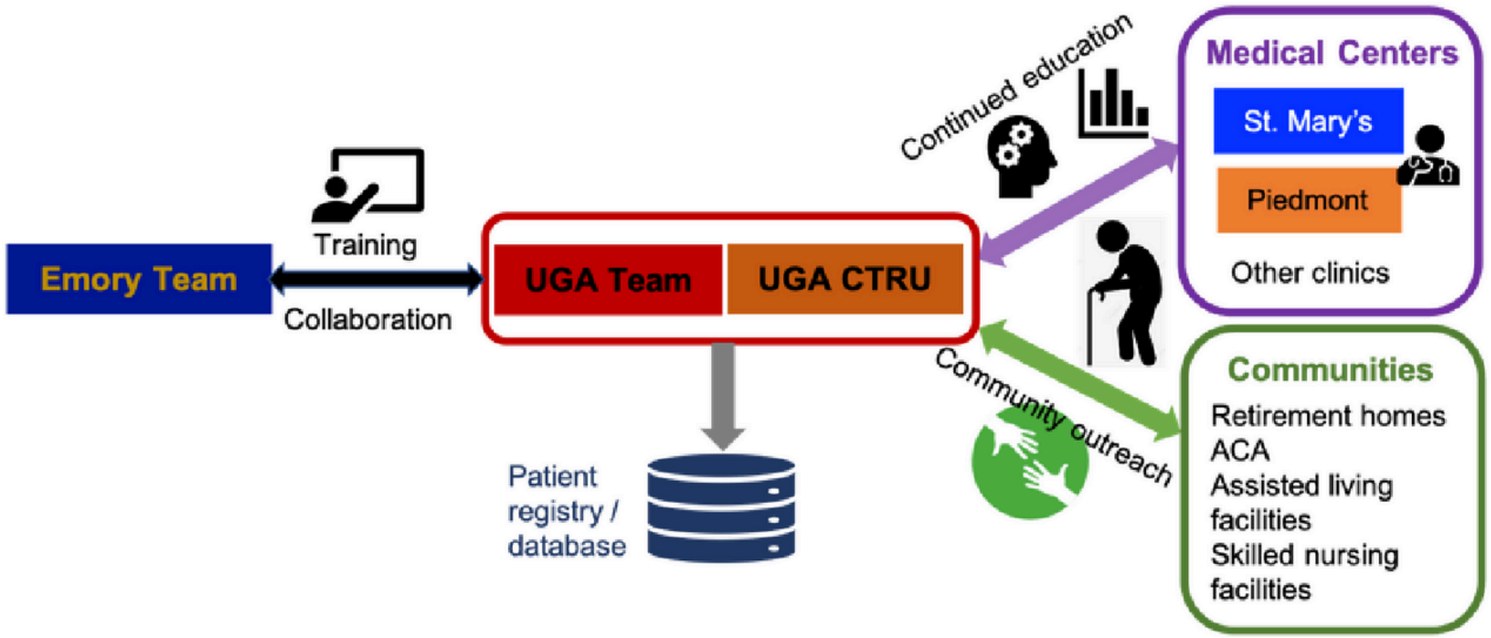
- Major health burden in the U.S., especially in Georgia ("Stroke Belt")
- A stroke occurs every 40 seconds nationwide



Possible contributing factors: higher prevalence of certain risk factors (e.g., hypertension; healthcare services available.

Our Client

- **Overall objective**: Create a sustainable, patient recruitment network to advance UGA-based stroke research.



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Project Overview

Overview

- **Overall Objective:**
  - **Create a sustainable, patient recruitment network to advance UGA-based stroke research.**

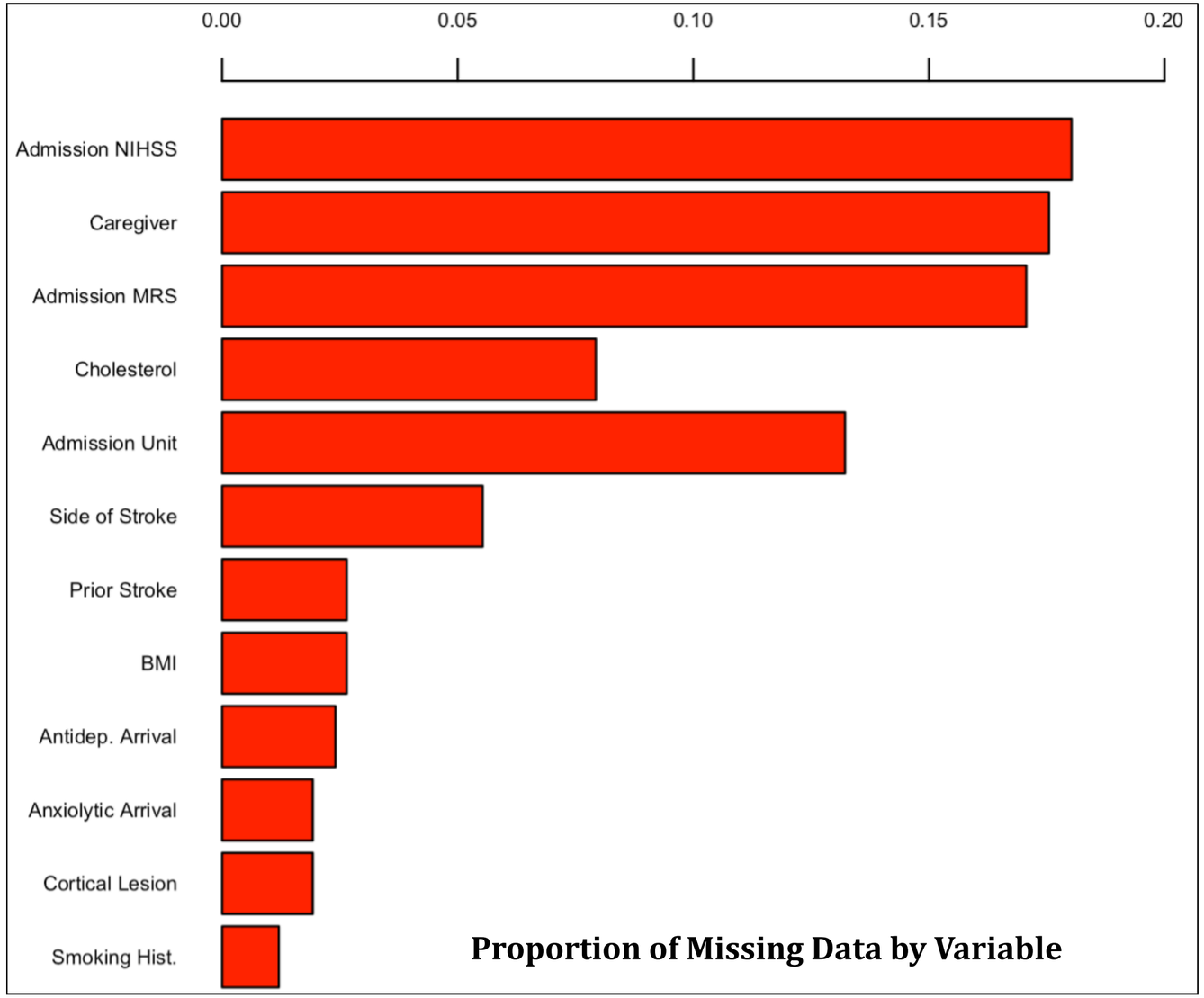
- **Objective 1:**
  - **Analyze the characteristics of stroke patients treated at Piedmont Athens Regional (PAR), focusing on stroke location and its relationship with patient demographics.**

- **Objective 2:**
  - **Evaluate the impact of key factors (e.g., NIHSS and MRS scores, obesity, diabetes, and other comorbidities) on hospital length of stay and discharge destination.**

Data Summary

- 580 observations and 220 variables
- Key variables: Age, Stroke Location, NIHSS Scores, MRS Scores, Length of Stay, Cholesterol, Obesity (BMI), Discharge Destinations, Medications
- Focusing on ischemic stroke patients who were admitted from 2019-2022

Data Quality and Missingness



Some patterns may be related to data collection practices, e.g., caregiver presence or depression screening may not have been consistently recorded in earlier years.

Several key predictors (like NIHSS, MRS, and Caregiver) had ~18–19% missingness. Removing those cases would significantly shrink the sample and bias the results.

NIHSS Scores

The National Institutes of Health Stroke Scale (NIHSS) is a standardized tool used to measure stroke severity

NIHSS Score	Stroke Severity
0	No Symptoms
1-4	Minor Stroke
5-15	Moderate Stroke
16-20	Moderate to Severe Stroke
21-42	Severe Stroke

NIHSS helps quantify stroke impact on the brain and predict outcomes:

Higher scores: Greater disability, worse prognosis.

Lower scores: Higher likelihood of functional recovery.

NIHSS Scores

4 Facial Palsy

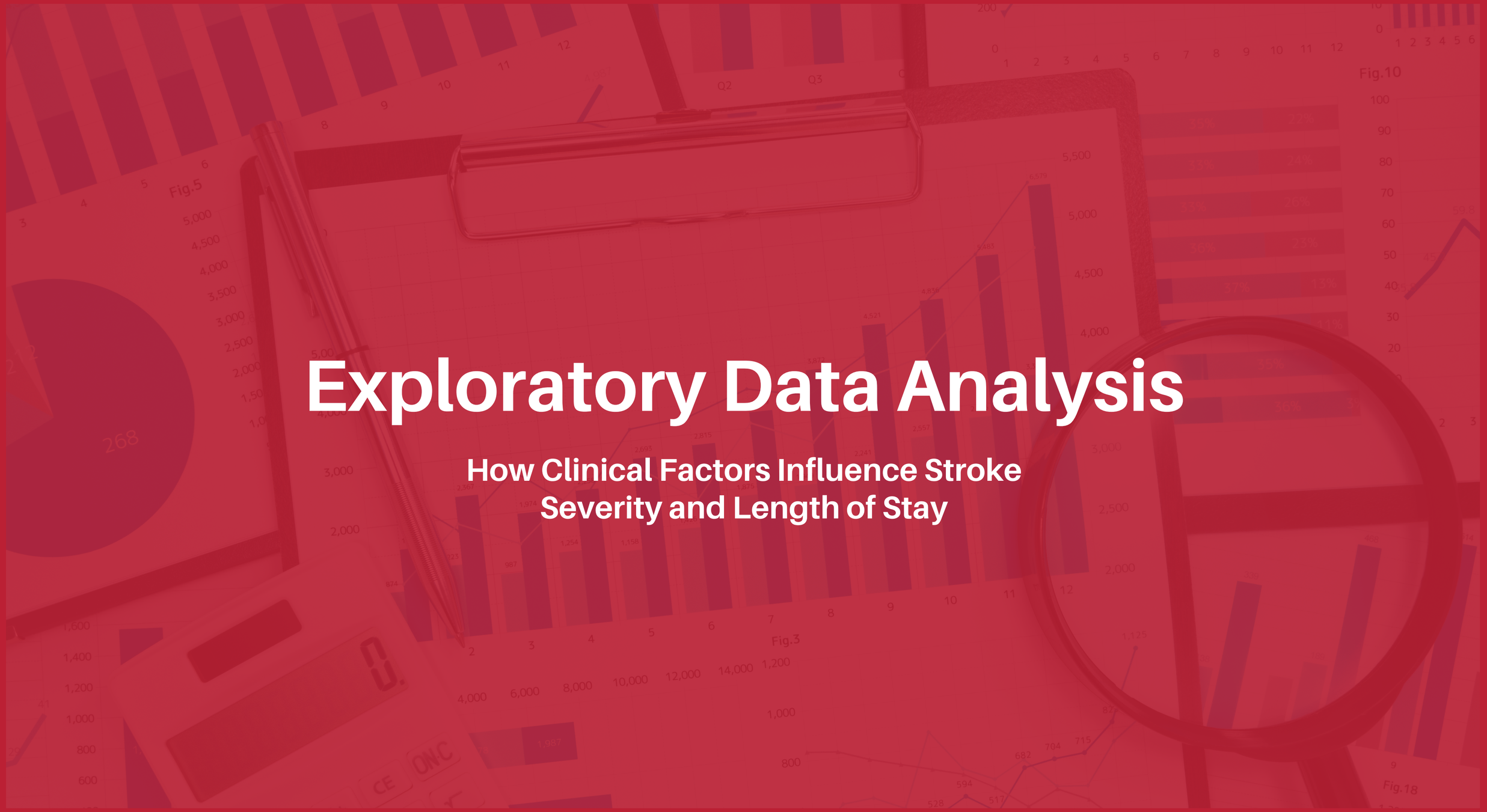
Instructions: Ask — or use pantomime to encourage — the patient to show teeth or raise eyebrows and close eyes. Score symmetry of grimace in response to noxious stimuli in the poorly responsive or non-comprehending patient. If facial trauma/ bandages, orotracheal tube, tape, or other physical barriers obscure the face, these should be removed to the extent possible.

Scale Definition	
0	**Normal** symmetrical movements.
1	**Minor paralysis** (flattened nasolabial fold, asymmetry on smiling).
2	**Partial paralysis** (total or near-total paralysis of lower face).
3	**Complete paralysis** of one or both sides (absence of facial movement in the upper and lower face).
	Score

MRS Scores

The Modified Rankin Scale (MRS) scores measure the degree of disability or dependence in daily activities, with higher scores indicating more severe impairment.

Modified Rankin Scale	
0	No symptoms
1	No significant disability. Able to carry out all usual activities, despite some symptoms.
2	Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities.
3	Moderate disability. Requires some help, but able to walk unassisted.
4	Moderate severe disability. Unable to attend to own bodily needs without assistance, and unable to walk unassisted.
5	Severe disability. Requires constant nursing care and attention, bedridden, incontinent.
6	Dead



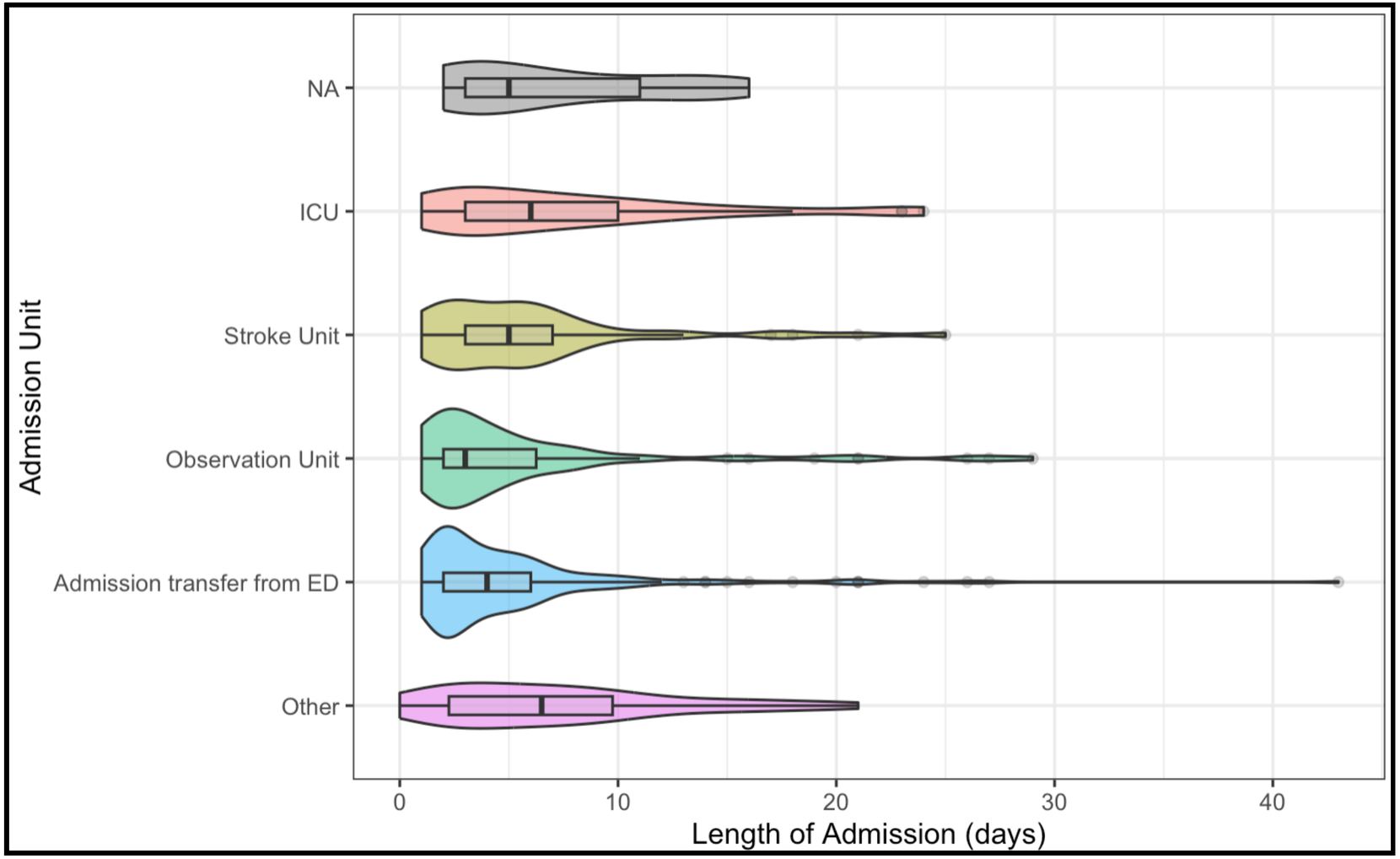
Exploratory Data Analysis

How Clinical Factors Influence Stroke Severity and Length of Stay

EDA 1

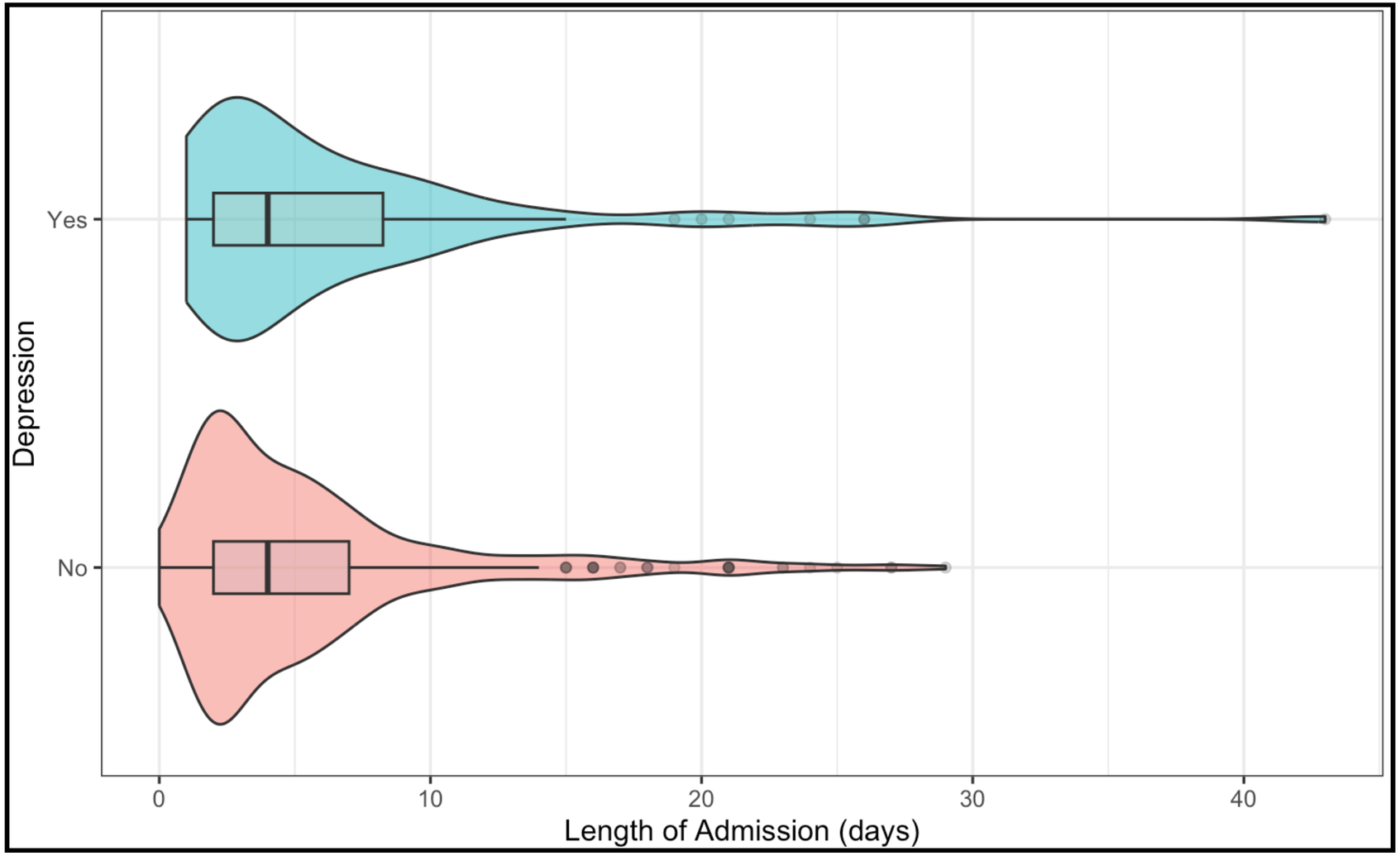
	Overall (N=416)	Admit transfer from ED (N=175)	Observation Unit (N=72)	Stroke Unit (N=46)	ICU (N=33)	Other/NA (N=90)
Age (years)						
Mean (SD)	69.2 (13.1)	68.8 (12.5)	69.6 (13.0)	66.1 (12.4)	65.4 (15.8)	72.8 (13.0)
Median [Min, Max]	69.0 [31.0, 99.0]	68.0 [38.0, 96.0]	71.0 [39.0, 96.0]	64.0 [38.0, 89.0]	66.0 [31.0, 96.0]	73.0 [36.0, 99.0]
Hypertension						
Yes	366 (88.0%)	161 (92.0%)	58 (80.6%)	38 (82.6%)	29 (87.9%)	80 (88.9%)
No	50 (12.0%)	14 (8.0%)	14 (19.4%)	8 (17.4%)	4 (12.1%)	10 (11.1%)
BMI (kg/m^2)						
Mean (SD)	27.9 (6.21)	28.3 (6.28)	27.5 (6.56)	27.8 (5.26)	27.9 (6.21)	27.7 (6.29)
Median [Min, Max]	27.0 [14.0, 59.5]	27.3 [15.0, 51.2]	26.5 [15.7, 57.2]	27.0 [17.9, 39.7]	26.1 [14.0, 40.5]	26.9 [16.5, 59.5]
Missing	11 (2.6%)	0 (0%)	3 (4.2%)	6 (13.0%)	2 (6.1%)	0 (0%)
Admission NIHSS						
Mean (SD)	5.25 (5.99)	4.39 (5.01)	3.75 (4.42)	4.03 (5.11)	10.0 (8.56)	6.81 (6.76)
Median [Min, Max]	3.00 [0, 31.0]	3.00 [0, 25.0]	3.00 [0, 21.0]	3.00 [0, 26.0]	9.00 [0, 31.0]	4.50 [0, 27.0]
Missing	75 (18.0%)	29 (16.6%)	15 (20.8%)	9 (19.6%)	2 (6.1%)	20 (22.2%)
Admission MRS						
Mean (SD)	2.75 (1.64)	2.88 (1.55)	2.55 (1.59)	2.00 (1.79)	2.11 (1.80)	3.39 (1.47)
Median [Min, Max]	3.00 [0, 6.00]	4.00 [0, 5.00]	3.00 [0, 4.00]	1.00 [0, 5.00]	2.00 [0, 4.00]	4.00 [0, 6.00]
Missing	71 (17.1%)	22 (12.6%)	8 (11.1%)	7 (15.2%)	6 (18.2%)	28 (31.1%)
Length of Admission (days)						
Mean (SD)	5.92 (5.63)	5.02 (5.42)	5.58 (6.16)	6.00 (5.26)	7.36 (6.45)	7.36 (5.17)
Median [Min, Max]	4.00 [1.00, 43.0]	3.00 [1.00, 43.0]	3.00 [1.00, 29.0]	5.00 [1.00, 25.0]	6.00 [1.00, 24.0]	6.00 [1.00, 21.0]
Discharge Destination						
Home with no needs	179 (43.0%)	111 (63.4%)	28 (38.9%)	23 (50.0%)	8 (24.2%)	9 (10.0%)
Home health or assisted living	73 (17.5%)	10 (5.7%)	19 (26.4%)	5 (10.9%)	10 (30.3%)	29 (32.2%)
Subacute rehab.	65 (15.6%)	12 (6.9%)	15 (20.8%)	12 (26.1%)	9 (27.3%)	17 (18.9%)
Inpatient or acute rehab.	36 (8.7%)	18 (10.3%)	4 (5.6%)	4 (8.7%)	5 (15.2%)	5 (5.6%)
Hospice/Expiration	35 (8.4%)	2 (1.1%)	2 (2.8%)	1 (2.2%)	1 (3.0%)	29 (32.2%)
Other	13 (3.1%)	7 (4.0%)	4 (5.6%)	1 (2.2%)	0 (0%)	1 (1.1%)
Missing	15 (3.6%)	15 (8.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

EDA 2



Length of Admission Days by Admission Unit

EDA 3

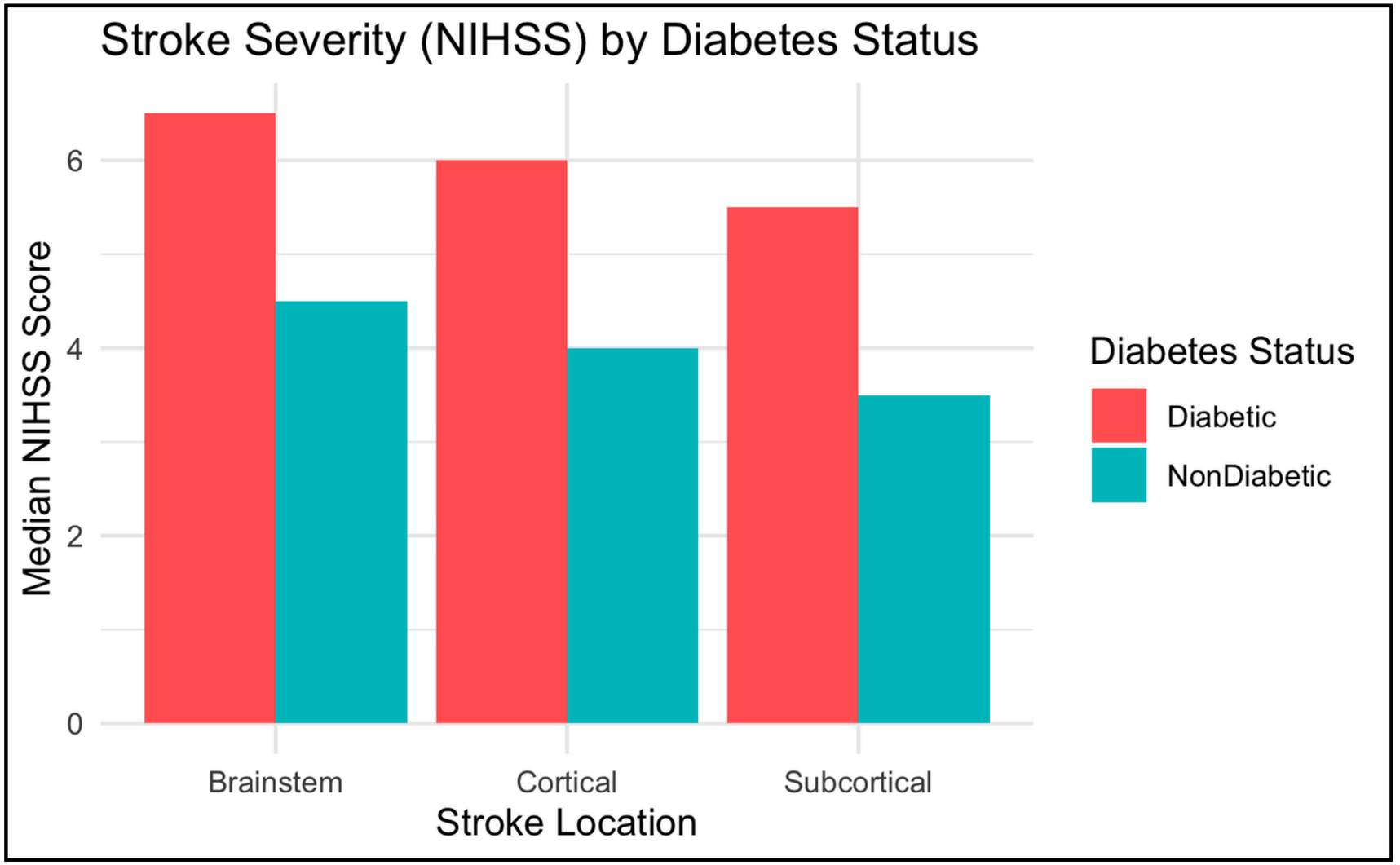


Length of Admission by Depression

Patients with depression had longer and more variable hospital stays, suggesting mental health may affect recovery

EDA 4

Diabetic patients had higher median NIHSS scores across all stroke locations



Methods

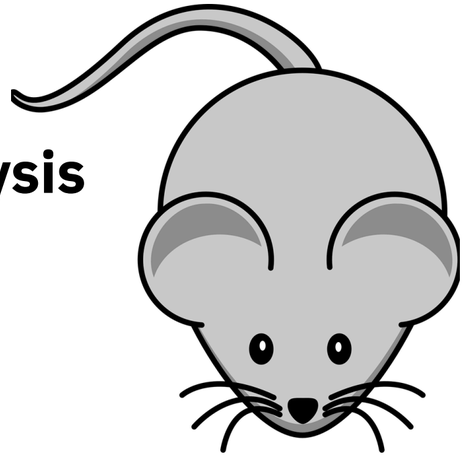
Research Question

Research Question: How do a stroke patient's pre-existing conditions, lifestyle and demographic factors, caregiver presence, and medication use influence their length of hospital stay and discharge destination?

MICE

Multiple Imputation by Chained Equation (MICE)

- **MICE imputes missing values based on the observed values multiple times to create several complete datasets.**
  - **m = 100**
- **For each variable with missing data:**
  - **It uses predictive models to fill in missing values in a way that reflects the relationships between variables**
- **Repeat for each variable (except response) and run the respective analysis**



Methods 1

Goal 1: Predict Length of Hospital Stay

Method: Multiple Linear Regression (log-transformed response)

- **Predictors: Stroke severity (NIHSS, MRS), stroke characteristics, demographics, comorbidities (e.g., diabetes, hypertension), medication use, caregiver status**
- **Ran MICE and fit the full model on the 100 datasets, then pooled the results**
- **Variable selection: Stepwise regression across 100 imputed datasets**
  - **Variables appearing 70% of the time were included in the final stepwise model**

$$\log[\text{Length of admission days}_i] = \beta_0 + \beta_1 \text{AdmissionNIHSS}_i + \beta_2 \text{AdmissionMRS}_i + \beta_3 \text{Side of Stroke-Right}_i + \beta_4 \text{Side of Stroke-Bilateral}_i + \beta_5 \text{Cortical Lesion}_i + \beta_6 \text{AdmissionUnit-Observation}_i + \beta_7 \text{AdmissionUnit-Stroke}_i + \beta_8 \text{AdmissionUnit-ICU}_i + \beta_9 \text{AdmissionUnit-Other}_i + \beta_{10} \text{Prior Stroke}_i + \beta_{11} \text{Diabetes} + \beta_{12} \text{Hypertension} + \beta_{13} \text{IschemicHeartDisease} + \beta_{14} \text{Antidepressants}_i + \beta_{15} \text{Anxiolytics}_i + \beta_{16} \text{SmokingHistory-Former} + \beta_{17} \text{SmokingHistory-Current} + \beta_{18} \text{CaregiverPresence}_i + \beta_{19} \text{Race-Black}_i + \beta_{20} \text{Race-Other}_i + \beta_{21} \text{Age}_i + \beta_{22} \text{Sex-Male}_i + \beta_{23} \text{BMI}_i + \beta_{24} \text{Cholesterol}_i + \epsilon_i$$

Discharge Destinations

Hospital Expiration – Patient passed away.

Rehabilitation – Acute, subacute, or inpatient rehab for recovery.

Assisted Living & Skilled Nursing – Residential or 24/7 medical care.

Home-Based Care – With or without medical support.

Hospice & Other – End-of-life care or other locations.

Methods 2

Goal 2: Predict Discharge Destination

- **Method: Classification Tree**
- **Classes: 7 outcomes (e.g., home, rehab, hospice)**
- **Steps:**
  - **Train-test split (80:20)**
  - **Fit the classification tree before imputation**
  - **Imputed 100 datasets and fit trees**
  - **10-fold cross-validation to avoid overfitting**
  - **Pruned trees by minimum deviance**

Results

Results 1

Table 1: Regression Table of Full Model

Variable	Estimate	Standard Error	Statistic	Degrees of Freedom	p-value
Intercept	6.0726191	0.40977	4.40192	351.2155	< 0.001
Admission NIHSS	1.0287248	0.00746	3.79788	301.3279	< 0.001
Admission MRS	1.1601740	0.02722	5.45812	286.7231	< 0.001
Side of Stroke - Right	1.0027638	0.08458	0.03268	345.2901	0.974
Side of Stroke - Bilateral	1.3883417	0.10694	3.06820	345.7877	0.002
Cortical Lesion	0.9031470	0.08089	-1.25927	351.5841	0.209
Admission Unit - Observation	1.1771662	0.10851	1.50322	319.0526	0.134
Admission Unit - Stroke	1.3688897	0.12347	2.54303	332.9483	0.011
Admission Unit - ICU	1.3342375	0.13958	2.06590	345.8818	0.04
Admission Unit - Other	1.5925556	0.14543	3.19972	339.7004	0.002
Prior Stroke	1.0248026	0.08235	0.29754	361.8485	0.766
Diabetes	1.0514078	0.07742	0.64755	368.6599	0.518
Hypertension	1.2346531	0.11887	1.77324	369.7454	0.077
Ischemic Heart Disease	1.2036517	0.23961	0.77360	373.6794	0.44
Antidepressants at Arrival	1.1022130	0.25014	0.38905	349.0300	0.697
Anxiolytics at Arrival	0.5568775	0.43868	-1.33447	183.8958	0.184
SmokingHistory - Former	1.0197627	0.08802	0.22233	367.5275	0.824
SmokingHistory - Current	1.0200891	0.10443	0.19049	367.0206	0.849
Caregiver Presence	1.0388143	0.08620	0.44181	307.6698	0.659
Race - Black	1.1313934	0.10403	1.18672	375.1170	0.236
Race - Other	1.0978130	0.09804	0.95189	368.8462	0.342
Age	0.9897331	0.00339	-3.04333	368.3437	0.003
Sex - Male	0.9473847	0.07795	-0.69331	369.6269	0.489
BMI	0.9870940	0.00651	-1.99596	345.1508	0.047
Cholesterol	0.9985111	0.00085	-1.74744	330.0924	0.081

Results 1

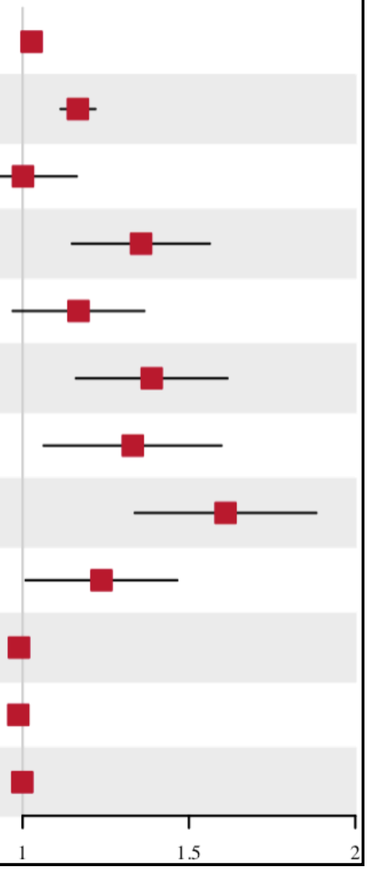
Final Stepwise Model

$$\log[\text{Length of admission days}] = \beta_0 + \beta_1 \text{AdmissionNIHSS}_i + \beta_2 \text{AdmissionMRS}_i + \beta_3 \text{Side of Stroke-Right}_i + \beta_4 \text{Side of Stroke-Bilateral}_i + \beta_5 \text{AdmissionUnit-Observation}_i + \beta_6 \text{AdmissionUnit-Stroke}_i + \beta_7 \text{AdmissionUnit-ICU}_i + \beta_8 \text{AdmissionUnit-Other}_i + \beta_9 \text{Hypertension} + \beta_{10} \text{Age}_i + \beta_{11} \text{BMI}_i + \beta_{12} \text{Cholesterol}_i + \epsilon_i$$

Results 1

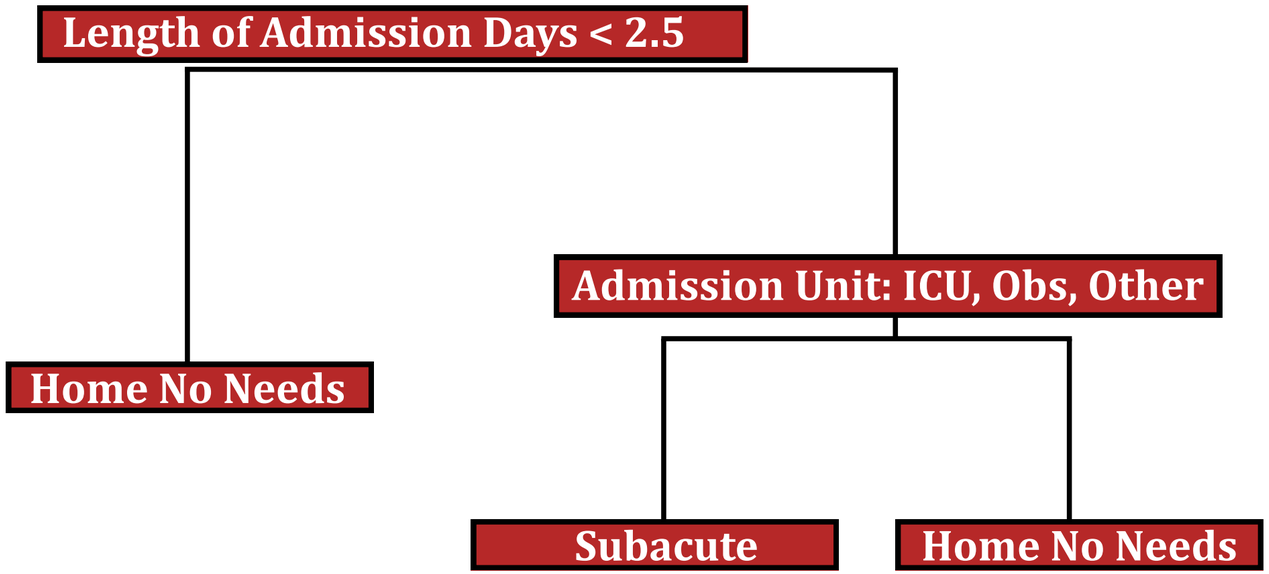
Forest Plot of Regression Coefficients of Stepwise Model

Covariates	Est.	95% C.I.	P-Val
Admission NIHSS	1.027	(1.013, 1.042)	< 0.001
Admission MRS	1.166	(1.114, 1.219)	< 0.001
Side of Stroke - Right	1.001	(0.839, 1.163)	0.991
Side of Stroke - Bilateral	1.356	(1.148, 1.563)	0.004
Admission Unit - Observation	1.168	(0.97, 1.366)	0.126
Admission Unit - Stroke	1.388	(1.16, 1.616)	0.005
Admission Unit - ICU	1.331	(1.063, 1.598)	0.037
Admission Unit - Other	1.61	(1.337, 1.883)	< 0.001
Hypertension	1.237	(1.009, 1.465)	0.069
Age	0.989	(0.983, 0.995)	< 0.001
BMI	0.987	(0.975, 0.999)	0.037
Cholesterol	0.999	(0.997, 1)	0.114



Model based on 100 imputed datasets. Predictors appearing 70% of the time were included (R^2 = 0.24).

Results 2



Pruned Classification Tree

Patients < 2.5 days → Often discharged home with no needs

Longer stays → More likely to go to rehab, ICU, or hospice

- Data: 382 stroke patients, split into training (305) and test (77) sets
- Variables included: Stroke severity, age, BMI, diabetes, caregiver presence, smoking, etc.
- Initial accuracy: 48.1% (pre-imputation)
- 100 trees were pruned (by deviance):
  - Mean accuracy: 50.8%
  - Best model (across 100 imputed datasets) reached 57.1% accuracy

Conclusion

Insights

- NIHSS and MRS scores, along with admission unit, were the strongest predictors for length of hospital stay
- Most patients were discharged home with no needs, making it harder for the model to accurately predict less common outcomes

Modeling

- Used multiple linear regression with multiple imputation and stepwise selection
- Applied a pruned classification tree for discharge prediction (best accuracy: 57.1%)
- Prioritized interpretability over complex models

Implications

- Informs early identification of patients likely to have longer stays
- Supports targeted patient recruitment for future stroke research
- Provides a foundation for improving stroke care planning

Questions?