Stroke Audit Machine Learning (SAMueL) Workshop 1

Investigating variation in clinical decision-making with explainable AI

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What will we cover?

- What's the problem?
- What's the question?
- Modelling the emergency stroke pathway
- Machine learning overview
- Model accuracy and simplification
- SHAP?
- Drivers of thrombolysis across all hospitals
- Example patients - what do different hospitals do? What would you do?
- General discussion (but please feel very free to ask questions, or comments, as we go along!)

What's the problem?

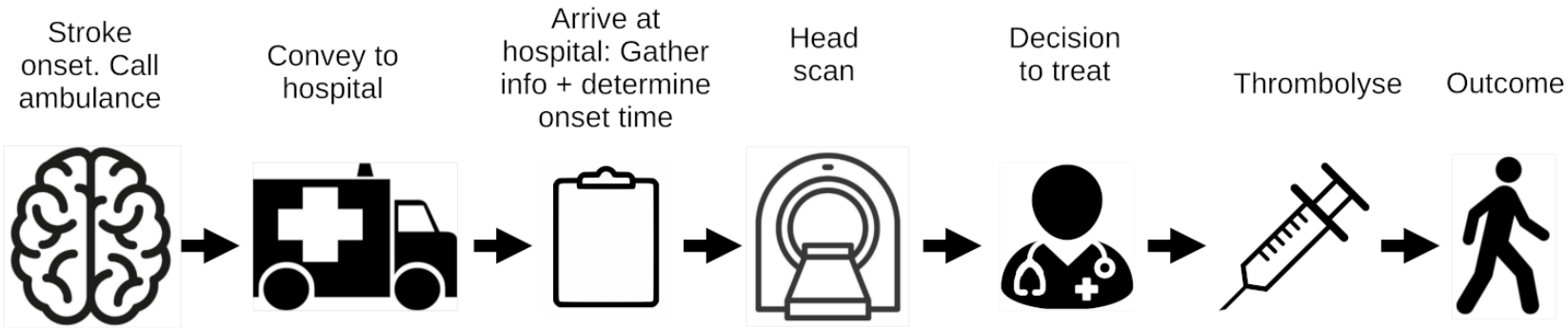
- Thrombolysis rates in England and Wales are stable at 11-12% against a NHS Long Term Plan target of 20%.
- Thrombolysis rates at individual hospitals range from 5% to 25%.

What's the question?

What causes this variation in thrombolysis rates, and what could reasonably be achieved at each hospital (allowing for each hospital's own patient population)?

> *"Your decision to treat or not treat . . . That's the difficult part. That's the grey area where everyone does a different thing."*
>
> — Stroke Consultant during interviews for SAMueL

Breaking down the emergency stroke pathway into key steps

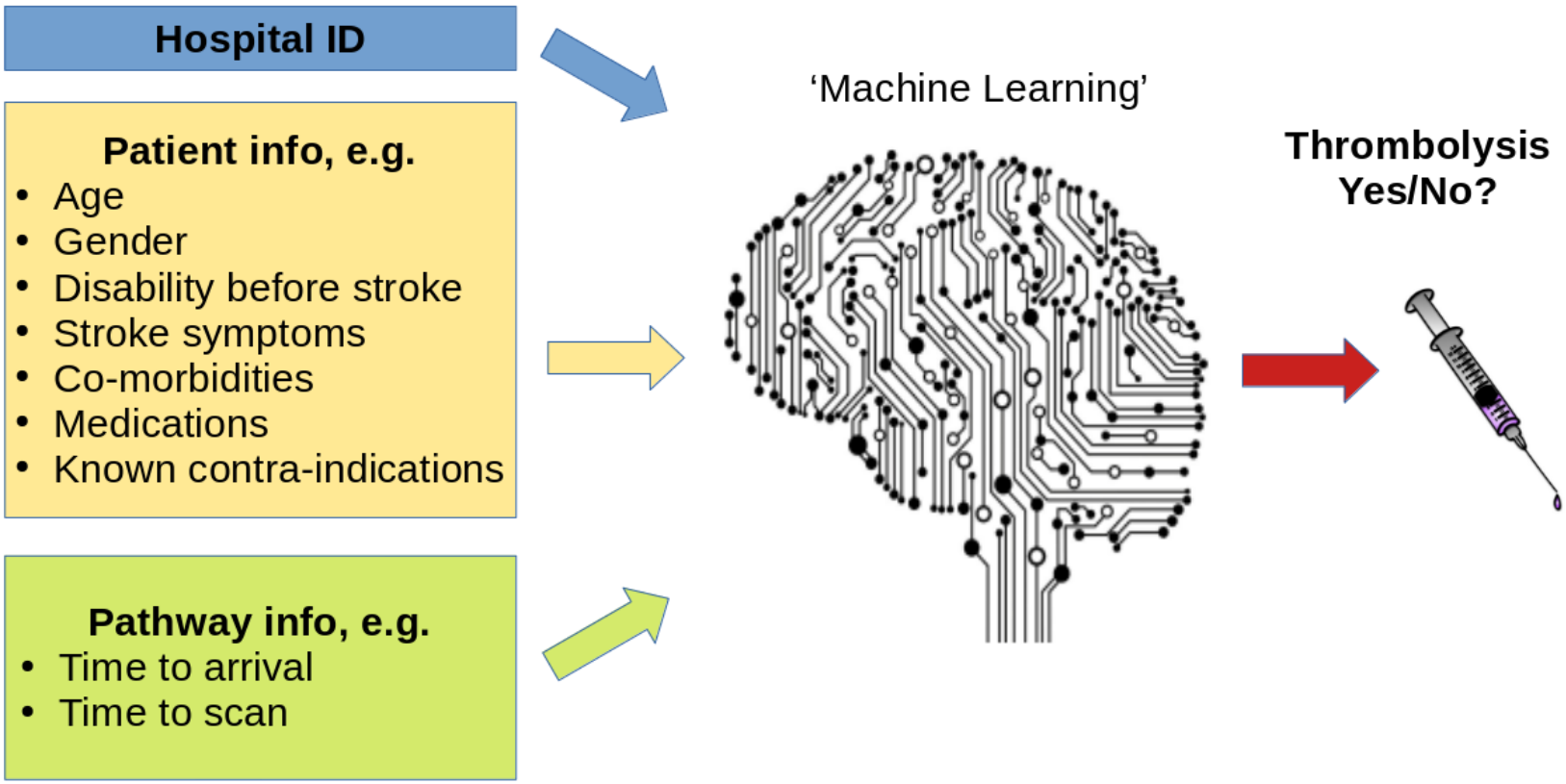


We can model key changes to pathway:

- What if the pathway were faster?
- What if hospital determined the stroke onset time in more patients?
- What if clinical decision-making was like that of *benchmark* hospitals? (Predict what treatment a patient would receive at other hospitals).

We model these changes with a hospital's own patient population, to allow for inter-hospital variation in patient population characteristics.

Machine learning overview



Machine learning (and nearly all *artificial intelligence*) is based on the simple principle of recognising similarity to what has been seen before.

We accessed 240,000 emergency stroke admissions in England and Wales over three years.

Model accuracy, and simplification

Our machine learning models use XGBoost classification, and are based on all patients who arrive within 4 hours of known stroke onset.

The full model has 61 patient features:

- Overall accuracy = 85.2%
- Best combined sensitivity and specificity = 84.3%
- ROC AUC = 0.921

A simplified model with 8 features

- Overall accuracy = 84.8%
- Best combined sensitivity and specificity = 83.8%
- ROC AUC = 0.916

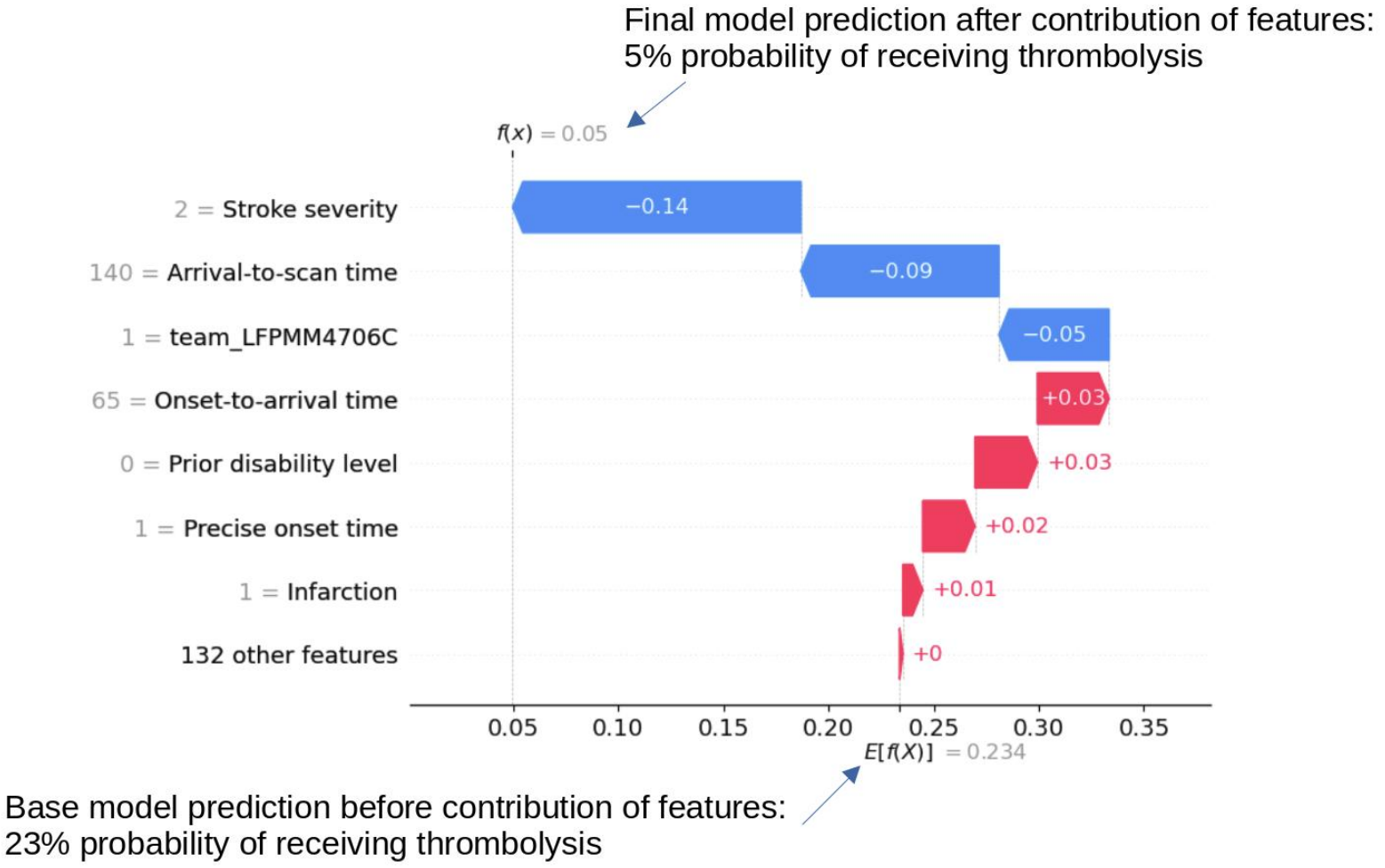
The 8 features of the simplified model are:

1. Arrival-to-scan time
2. Stroke type (infarction/haemorrhage)
3. Stroke severity (NIHSS)
4. Precise or estimated stroke onset time
5. Prior disability level (mRS)
6. Stroke team
7. Use of AF anticoagulants
8. Onset-to-arrival time

There are only very weak correlations between the selected features with no R-squared being greater than 0.05.

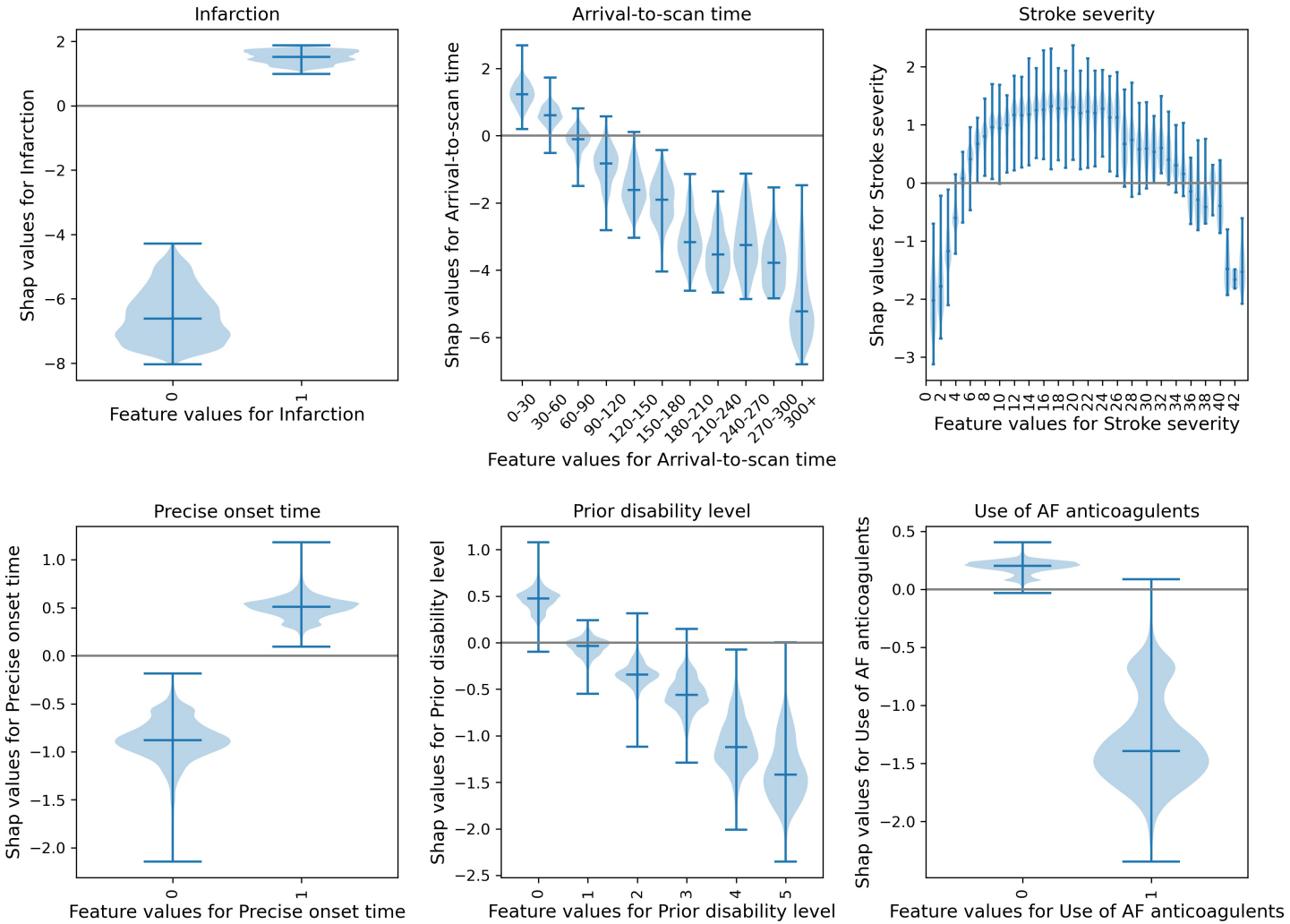
Explaining model predictions with SHAP values

SHAP values show the influence of features (even for *'black box'* models).



What drives use of thrombolysis across all hospitals?

Note: SHAP values here are *log odds*. Each step-change in value of ± 1 changes the chances of receiving thrombolysis about 3-fold. (Plots are in order of feature importance.)



Investigating how hospitals differ in thrombolysis decision-making (Patient 1: Base patient)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- NIHSS = 15
- Prior disability level = 0
- Precise onset time = Yes
- Use of AF anticoagulents = No

Investigating how hospitals differ in thrombolysis decision-making (Patient 1: Base patient)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- NIHSS = 15
- Prior disability level = 0
- Precise onset time = Yes
- Use of AF anticoagulents = No

Our model predicts 131 out of 132 (99%) hospitals would give this patient thrombolysis.

Investigating how hospitals differ in thrombolysis decision-making (Patient 2: Milder stroke)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- *NIHSS = 4*
- Prior disability level = 0
- Precise onset time = Yes
- Use of AF anticoagulents = No

Investigating how hospitals differ in thrombolysis decision-making (Patient 2: Milder stroke)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- *NIHSS = 4*
- Prior disability level = 0
- Precise onset time = Yes
- Use of AF anticoagulents = No

Our model predicts 97 out of 132 (73%) hospitals would give this patient thrombolysis.

Investigating how hospitals differ in thrombolysis decision-making (Patient 3: Pre-stroke disability)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- NIHSS = 15
- *Prior disability level = 3**
- Precise onset time = Yes
- Use of AF anticoagulents = No

*Moderate disability; requires some help, but able to walk without assistance.

Investigating how hospitals differ in thrombolysis decision-making (Patient 3: Pre-stroke disability)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- NIHSS = 15
- *Prior disability level = 3**
- Precise onset time = Yes
- Use of AF anticoagulents = No

*Moderate disability; requires some help, but able to walk without assistance.

Our model predicts 114 out of 132 (86%) hospitals would give this patient thrombolysis.

Investigating how hospitals differ in thrombolysis decision-making (Patient 4: Estimated stroke onset time)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- NIHSS = 15
- Prior disability level = 0
- *Precise onset time = No*
- Use of AF anticoagulents = No

Investigating how hospitals differ in thrombolysis decision-making (Patient 4: Estimated stroke onset time)

Assuming there are no reasons not stated here to exclude a patient from use of thrombolysis, would you give this patient thrombolysis?

- Onset to arrival = 80 mins
- Arrival to scan = 20 mins
- Infarction = Yes
- NIHSS = 15
- Prior disability level = 0
- *Precise onset time = No*
- Use of AF anticoagulents = No

Our model predicts 84 out of 132 (64%) hospitals would give this patient thrombolysis.

Key findings

General observations about thrombolysis use: The chance of receiving thrombolysis is increased by:

- *Shorter arrival-to-scan times*
- *Mid-level stroke severity*
- *Precise onset time*
- *Lower pre-stroke disability*

Lower thrombolysing units are particularly less likely to give thrombolysis to patients with:

- *Low or high stroke severity*
- *Higher pre-stroke disability*
- *Estimated onset time*

Possible questions for discussion - but please comment as you wish!

- Does anything surprise you here, and do these findings reflect your own experiences?
- What are your experiences in treating mild strokes and patients with estimated stroke-onset times?
- What might you do with the knowledge that different hospitals have different attitudes to mild strokes and patients with estimated stroke-onset times? Would it stimulate you to consider your own practice?
- Why do you think pre-stroke disability appears influential in thrombolysis decision-making?
- Do you find SHAP understandable?
- Do the patient examples help? Would you like them filled out more, or do you prefer to see the key decision-makign data in the model?

Thank you!!

Thank you for your time and attention!

Reserve slides

When will low thrombolysing units not use thrombolysis when higher thrombolysing would?

Here, a high SHAP shows when a low-thrombolysing unit will reject use of thrombolysis when a higher thrombolysing hospital would use thrombolysis. (Plots are in order of feature importance.)